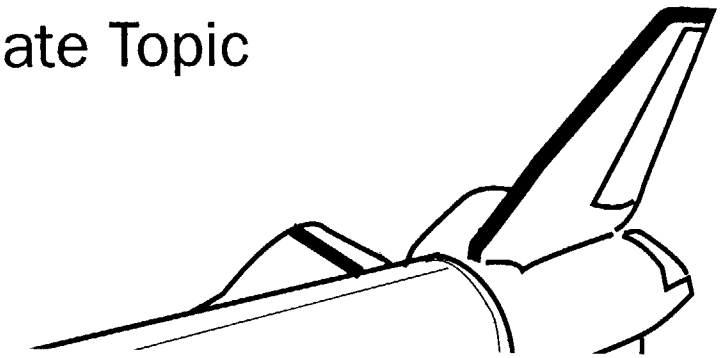
NASA-TM-109220

TN-12-TM

Debate Handbook

1990-91 National High School Debate Topic

"Resolved: That the United States Government Should Significantly Increase Space Exploration"



(NASA-TM-109220) DEBATE HANDBOOK. THE 1990-1991 NATIONAL HIGH SCHOOL DEBATE TOPIC. RESOLVED: THAT THE US GOVERNMENT SHOULD SIGNIFICANTLY INCREASE SPACE EXPLORATION (NASA) 67 p

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NASA

JULY 1990

Table of Contents

Spacelink

Spacelink: An Electronic Information System for Educators 2

Congressional Testimony

Statement by Admiral Richard Truly Presenting the President's FY 91 Budget Request for NASA 5

Statement by J. R. Thompson Reviewing the Progress and Plans for the National Aero-Space Plane Program . . 10

Statement by Arnold Aldrich on NASA's Office of Aeronautics, Exploration, and Technology (OAET) 13

Statement by Dr. Lennard Fisk on the Office of Space Science and Applications Plans and Objectives 26

Statement by Dr. Lennard Fisk Discussing NASA's Plans for a Mission to Planet Earth 33

Statement by James Rose on Commercial Development in Space 40

Statement by Dr. William Lenoir Discussing the Space Station *Freedom* Program 50

Statement by Dr. William Lenoir Reviewing the Office of Space Flight's FY 91 Budget 63

Statement by Charles Force Presenting the FY 91 Budget Request for the Office of Space Operations 74

Speeches and Quotes

Remarks by President Bush at the Marshall Space Flight Center, Huntsville, Alabama 82

Remarks by President Bush at the Texas A&I University Commencement Address 84

Remarks by President Bush at the 20th Anniversary of Apollo Moon Landing 87

Remarks by Vice President Quayle at the Sixth National Space Symposium, Colorado Springs, Colorado 89

Statement by Admiral Richard Truly on the Importance of Mathematics and Science Education in America . . . 94

Excerpts from the Remarks by Admiral Richard Truly at the Down Town Association, New York, New York . . 99

Excerpts from the Remarks by Admiral Richard Truly to the Town Hall of California, Los Angeles, California . 103

Speech by Arnold Aldrich on the Space Exploration Initiative 108

NASA Clips and Quotes 113

Publications & Presentations

Office of Space Science & Applications 1990 Strategic Plan 116

Office of Aeronautics, Exploration and Technology Presentation on President Bush and the Space Exploration Initiative 150

Excerpts from "Space Shuttle: The Journey Continues" 166

U.S. Global Change Research Program 174

The Earth Observing System 184

Office of Commercial Programs Progress Report – 1989 194

Spinoff Brochure 209

Space Program Benefits 217

Background Data and Information

Semiannual Procurement Report – Fiscal Year 1990 220

Report on the Private Sector Economic & Employment Benefits to the Nation and to Each State of Proposed FY 1990 NASA Procurement Expenditures 224

NASA DEBATE HANDBOOK

1990-91 DEBATE TOPIC

Talk to NASA

NASA Spacelink isn't just a machine. It's maintained by NASA people who would like to hear from you if you have questions, comments or suggestions. If you are an educator, you may use the system to communicate directly with NASA education specialists who can provide further assistance.

When you log off NASA Spacelink using Option 1 from the Main Menu, you will be asked if you wish to leave a message for NASA. You may enter as many as 15 lines to be read by the NASA Spacelink System Administrator. To end your message, enter a blank line. The System Administrator reads messages each business day and will respond to you through regular mail or with a note which will appear the next time you log on.

The following organizations provide information for NASA Spacelink:

NASA Headquarters
Washington, D. C.

Ames Research Center
Mountain View, California

Goddard Space Flight Center
Greenbelt, Maryland

Jet Propulsion Laboratory
Pasadena, California

Johnson Space Center
Houston, Texas

Kennedy Space Center
Florida

Langley Research Center
Hampton, Virginia

Lewis Research Center
Cleveland, Ohio

Marshall Space Flight Center
Huntsville, Alabama

Stennis Space Center
Bay St. Louis, Mississippi

Computer
Access Number
(205) 895-0028

Data Format 8-NONE-1

NASA Space Link

An Electronic Information System For Educators

Current NASA News
Aeronautics
Space Exploration
NASA and its Centers
NASA Educational Services
Classroom Materials
Space Program Spinoffs

What's NASA Spacelink?

NASA Spacelink is a collection of NASA information and educational materials stored on a computer at the Marshall Space Flight Center in Huntsville, Alabama. The system may be accessed over regular telephone lines. It is designed to communicate with a wide variety of computers and modems, especially those most commonly found in classrooms and homes. NASA Spacelink is free, but you'll owe your phone company for long distance calls.

NASA Spacelink is provided by the NASA Educational Affairs Division and is operated by the Public Services and Education Branch of the Marshall Center Public Affairs Office. System software was developed for NASA by the Data General Corporation. The system has a main memory of 14 megabytes (14 million characters), and disk storage space for 708 megabytes. It can communicate with twelve callers simultaneously at 300, 1200, or 2400 baud.

What's in the System?

NASA Spacelink Main Menu

1. **Log Off NASA Spacelink:** Use when leaving the system. Contains procedure for entering a message to NASA.

2. **NASA Spacelink Overview:** A review of the introduction to NASA Spacelink, an explanation of XMODEM, a listing of new, updated files, and a procedure for revising the address information provided at initial logon.

3. **Current NASA News:** Dated information subject to daily change. Topics include listings of NASA educational workshops for teachers, news releases, Shuttle status reports, copies of recent speeches by NASA managers, TV schedules, the Shuttle manifest, and current Shuttle flight activities.

4. **Aeronautics:** Information on current and past NASA research in aeronautics, including documents on the National Aerospace Plane, aircraft propulsion, wind tunnels, and aircraft design.

5. **Space Exploration Before the Shuttle:** Historical information on the U.S. Space Program, including documents on the Mercury, Gemini, Apollo and Skylab programs, as well as information on planetary probes, satellites, and other unmanned missions of the 50s, 60s, and 70s.

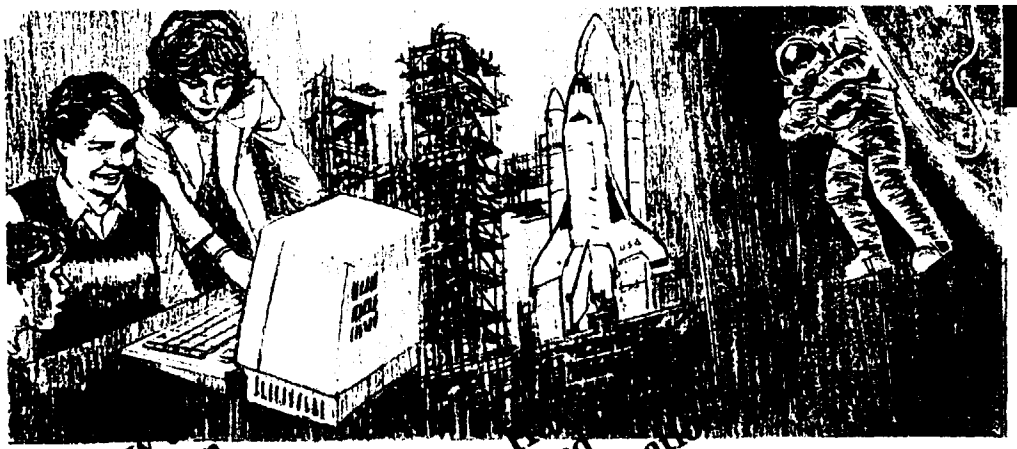
6. **Space Exploration Beyond The Shuttle:** Comprehensive material on the Space Shuttle and Shuttle payloads, as well as current information on topics such as Space Station Freedom, astronauts, planetary probes, space observatories, and satellites. Generally, this area contains material on aerospace research in the 80s and beyond.

7. **NASA and its Centers:** Overviews of the responsibilities and resources of all the NASA centers and other installations.

8. **NASA Educational Services:** A listing of all the major NASA educational programs. Subjects include the Aerospace Education Services Project, Urban Community Enrichment Program, Summer High School Apprenticeship Research Program, Space Science Student Involvement Project, Teacher Workshops, Educators Mailing List, Telelectures, Teacher Resource Centers, and Science Fair support.

9. **Classroom Materials:** A variety of information useful in the classroom, including space science lesson plans and activities (all grade levels and many subjects), astronomy information, film/video list, computer programs, career information, computer graphics, and a source list for pictures, posters, and other educational materials.

10. **Space Program Spinoffs:** Reports on the many ways in which Space Program research has been adapted to benefit industry and the public.



How to Sign On

Use the instructions that came with your modem and communications software when calling NASA Spacelink. The computer access number is 205-895-0028 and the data word format is 8 data bits, no parity, and 1 stop bit. Your computer may send carriage returns or line feeds, but not both.

When your computer connects with NASA Spacelink, a welcome screen will appear with instructions for logging on to the system. When you press Return, NASA Spacelink will ask first for a Username, and then a Password. To log on as a first-time caller, you must enter the Username NEWUSER and the Password NEWUSER, after which you will be asked to enter the number of lines your computer will display at one time (usually 24). NASA Spacelink will pause each time this number of lines is displayed, to allow time for reading. To continue after a pause, press Return. Any time you type a response to the system, enter the response by pressing Return.

As a first-time caller, you will receive an introduction to NASA Spacelink and you will be asked to provide some background information, including your name and address. NASA will need this information should you request material to be sent by mail. The information will also be helpful in planning future development of NASA Spacelink.

Most important, you will be asked to assign yourself a personal Username and Password to be used when you call again.

How to Find Information

After the introduction, the NASA Spacelink Main Menu will be displayed. Type the number of a menu item, and press your computer's Return key. You will find one or more submenus under each item in the main menu.

Choose menu items until you reach the desired document. For example, if you want to plan a 6th grade lesson around food for astronauts, choose item 9 from the Main Menu (Materials for Classroom Use). From the next menu choose item 2 (Living in Space Activities). From the next menu choose item 2 (Food Lesson Plans). Your final menu choice will be item 6 (Grades 4-6), a document containing suggested activities for sixth grade students. Before NASA Spacelink sends most documents, you'll be asked to choose a method for receiving it (View or XMODEM). To view the document on your computer, just press the Return key.

How to Save Information on Your Computer

There are two methods for saving NASA Spacelink information. Virtually any communications software will allow you to capture NASA Spacelink documents as they are displayed on your screen. You may save the information on disk or send it to your printer. The other method is to use XMODEM, a public domain file transfer protocol.

XMODEM allows information to be transferred from one computer to another with an enhanced degree of accuracy. To take advantage of this feature, your communications software must support XMODEM. Computer programs and graphics may be downloaded from NASA Spacelink ONLY by using the XMODEM checksum protocol, so for these documents you'll not be given the view option.

To perform an XMODEM transfer, first go to the desired NASA Spacelink document. When you are asked to choose between View and XMODEM, enter X. NASA Spacelink will tell you the size of the file in 128-byte blocks, and wait for you to activate the XMODEM option in your software. Then, your computer will signal NASA Spacelink to begin the transfer, and you will be notified as each block is received. When the transfer is complete, you may press return to review the previous menu

NASA Spacelink Control Keys

Key	Response
C	Continuous Scrolling
S	Stop Viewing Document
Control/S	Pause
Control/Q	Cancel Control/S
Control/X	Cancel XMODEM

NOTE: At lower baud rates, NASA Spacelink will respond slowly to "S" and "Control/S."

CONGRESSIONAL TESTIMONY

This section includes Congressional Testimony offered by NASA officials during the first half of 1990. It offers insight into the current NASA program and a vision for agency planning and programs in the future.

Citations are noted in the cover page for each testimony.

Other information from these hearings should be available in the public record.

NASA
National Aeronautics and Space Administration

Hold for Release Until
Presented by Witness

March 20-22, 1990

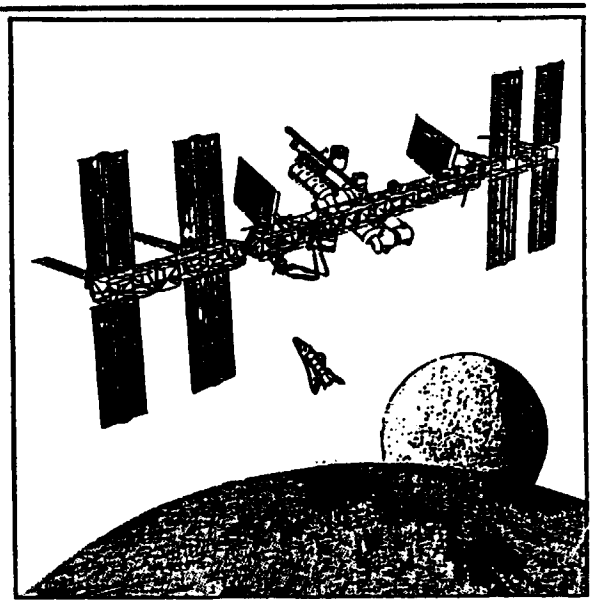
Subcommittee on VA—HUD—Independent Agencies

Committee on Appropriations

House of Representatives

Statement by:

Admiral Richard H. Truly
Administrator



101st Congress

Statement of

Richard H. Truly
Administrator

National Aeronautics and Space Administration

before the

Subcommittee on VA-HUD-Independent Agencies

Committee on Appropriations

House of Representatives

Mr. Chairman and Distinguished Members of the Subcommittee:

I welcome this opportunity to present the President's FY 1991 budget request for the National Aeronautics and Space Administration, and to discuss the future direction of our Nation's civil space and aeronautics program which this budget represents. We have just concluded a year in which NASA maintained its role as a principal symbol of American technological and scientific prowess. An improved and more reliable Space Shuttle fleet was employed in a demanding series of missions, and a 12-year hiatus in planetary launches ended, as sophisticated spacecraft were launched on journeys to Venus and Jupiter. At the same time, 12 years of innovation and ingenuity by a control team of NASA scientists, engineers and technicians culminated in Voyager 2's encounter with the planet Neptune, an event that captivated a world audience.

President Bush is committed to a sustained, continuing and balanced program which advances U.S. leadership in aeronautics and space. The President's FY 1991 budget request for NASA of $15.1 billion in discretionary authority provides the resources necessary to maintain us on a steady course toward achievement of that goal. A summary of NASA's FY 1991 budget request is appended to this statement.

The President's budget request acknowledges that NASA's activities embody highly significant contributions to our efforts toward building a better America. Our programs are aimed at building mankind's store of knowledge about our planet and our universe, at helping to understand and to protect our fragile environment, at enhancing U.S. economic competitiveness, and contributing to an intangible but critical national pride in ourselves and our accomplishments as a Nation.

One of the most valuable contributions of the U.S. space program is that it provides a strong stimulus to young students' interest in science, engineering and mathematics education. This budget, in fact, enhances specific NASA efforts aimed at using space endeavors in classrooms around the country to help in assuring American preeminence in math and science education by the end of the century. In addition, NASA's extensive international cooperative activities in programs like Space Station Freedom and Mission to Planet Earth allow our efforts to serve U.S. foreign policy, as well as domestic policy, goals. NASA is a vital part of the American infrastructure. Investment in civilian space research and technology has contributed to America's infrastructure of today and will serve as a foundation for America's infrastructure of tomorrow.

SCIENCE, TECHNOLOGY AND EXPLORATION

NASA's mission embodies three major areas of endeavor: science, technology, and exploration. Our undertakings in these areas have intrinsic merit while, at the same time, serving broad national objectives. I would like to describe briefly some of our activities in these areas and attempt to place those activities in a broader national context. You will be receiving more detailed testimony on all our programs over the coming weeks.

Innovative Science

In space science, we are expanding our base of knowledge with benefits both foreseen and unforeseen. We have entered a "golden age of space science" with 36 major missions planned over the next five years. We are returning to the planets with Magellan, Galileo, Mars Observer, and CRAF/Cassini. We have emerged from a period of more than a decade of virtually no activity. From now until well into the next century, there will be an uninterrupted sequence of U.S. planetary missions in their primary phase of exploration. Before the end of the century, we will have launched three Great Observatories, starting with Hubble Space Telescope this spring. These are exciting times--our understanding of the universe will soon increase manyfold. In addition to our robotic programs, science is also served by men and women aboard the Space Shuttle, as it will be in the future on Space Station Freedom. Microgravity research in materials and life sciences is enhancing our fundamental understanding of materials processing and life functions. This fundamental understanding will lay the groundwork for future manned activity in space and also for future commercial activity on the ground.

A critical element in our science program is Mission to Planet Earth, NASA's major contribution to the U.S. Global Change Research Program. This budget request initiates the Earth Observing System as a major part of our activities in service of the global environment. We will monitor the Earth, tracking environmental changes over many years. Just as we study the other planets, we will study our own--looking at the complex interactions among the land, the sea, the ice, and the atmosphere. We must understand carbon dioxide build-up, ozone depletion, deforestation, and desertification as an essential element of intelligent action. We will do our part to improve this planet for our children and our grandchildren.

Competitive Technology

NASA has been a preeminent force in the development of America's advanced technology over the past 30 years. We develop technology to do our space flight programs and to develop a base to support our national leadership in aeronautics. This budget request contains investments in cutting-edge aeronautics and space technologies which will enhance U.S. competitiveness abroad and economic well-being at home. These efforts also support U.S. industry's interests in space commercialization.

Aeronautics in the United States is unique in its contribution to the balance of trade, to the transportation infrastructure for world commerce, and to our national security. It is also a symbol of U.S. technological might. NASA, as our country's focal point for aeronautical research and technology, will continue to address these critical issues with high-leverage technologies--advancing at a rate unmatched since the 1950's--in order to maintain and strengthen the U.S. competitive posture in aviation.

NASA continues to lead the development of the aeronautics technology base that is critical to the design of all future advanced aeronautical systems. Emphasis is being placed on numerical simulation techniques, including new, massively parallel computers, which will lead to further advances in the design of aircraft and propulsion systems and to the understanding of aerodynamics critical to more efficient flight. NASA will continue to develop long-term technology solutions to support the Federal Aviation Administration in addressing issues such as congestion, airspace safety, and aging aircraft. Advanced composite materials and structures research efforts will be increased to exploit new, higher temperature organic composite materials that will significantly lower the weight and cost of high-speed aircraft. The High-Speed Research program will address the critical environmental issues associated with

high speed civil transports, providing the foundation for future decisions on technological and aircraft development. These aeronautics programs will offer major payoffs in aircraft performance and capabilities and provide substantial positive impact on U.S. economic competitiveness.

Our joint effort with Department of Defense on the National Aero-space Plane spans the full spectrum of technology development. The results of this program could lead to a whole new generation of vehicles, to U.S. preeminence in high-speed aeronautics, and to rapid, flexible, and efficient access to space.

Investment in space technology is essential to maintaining the Nation's capabilities and to ensuring future U.S. leadership in space. Throughout all our technology development efforts, we seek new, innovative concepts. We will be working on automation and robotics, propulsion, power, information technology, and large structures and control, all of which will enable efficient, reliable access to Earth orbit, enhance operations in Earth orbit, and increase the effectiveness of science missions from Earth orbit. We will also be developing the range of critical technologies needed to expand human presence and activity into the solar system.

Bold New Explorations

On July 20 of last year, the President provided a focus which will guide this Nation's space efforts for decades to come. His Moon-Mars Initiative directs us to complete Space Station Freedom in the 1990's, then, in the 21st century, to return to the Moon, this time to stay, and to venture on to the planet Mars. In so doing, we are addressing one of the most fundamental of human needs--the need to explore and expand horizons. That innate desire fueled the discovery of America, our Westward expansion, and our treks to the Earth's polar regions.

It is with this budget that we will begin mankind's latest historic journey. We will be living and working permanently in space well before the end of this decade. And then we will be undertaking space exploration with our return to the Moon and journey to Mars. We will be casting the nets widely to capture America's creative energies. We will enlist the broadest possible involvement of U.S. industry, universities, and other Federal agencies and research facilities. And, in parallel with this search for new ideas from outside sources, we will continue our own efforts to conduct mission concept and systems analysis studies, science activities, and technology development efforts. These efforts will follow up on last fall's 90-Day Study which established a data base, and which will be one of the points of departure for our upcoming efforts.

Our early activities will focus on technology development with a search for new and innovative approaches--approaches which could have significant impacts on human exploration schedules, cost, risk, and performance. Spurred by this focus on technology development, those efforts will provide early ancillary benefits such as strengthening U.S. capabilities in key industries, stimulating science, engineering and mathematics education, and promoting excellence in science and engineering disciplines. The Moon-Mars Initiative will include robotic science missions as an integral part. This budget request includes a significant enhancement to Mars Observer which is scheduled for a 1992 launch, and final definition studies for two FY 1992 development starts--Lunar Observer and Lifesat. These missions, in addition to significantly advancing scientific knowledge of the Moon and Mars, will obtain data needed to assist in the design and development of subsequent human exploration systems and missions.

ENABLING INVESTMENTS

The high standards and difficult goals we reach for in NASA require investments in our people, facilities, and transportation capabilities to support our missions. The Space Shuttle, Space Station Freedom, Expendable Launch Vehicles, the Tracking and Data Relay Satellite System, and the unique capabilities of NASA's facilities and workforce all form the critical base, without which none of our missions can be achieved.

The Space Shuttle is vital to our space objectives. The program continues to demonstrate its successful return to flight, accomplishing nine remarkable flights since September 1988. The missions have been smooth, and we have stayed extremely close to our target launch dates - particularly on the planetary missions with narrow launch windows. We remain committed to safe and reliable flight operations and will continue to seek ways to increase our margin of safety in what is inherently a risky and unforgiving operational regime. The new manifest recently issued includes eight flights in FY 1990, 10 flights in FY 1991, and 11 flights in FY 1992, as we work toward a flight rate of 12 per year.

In addition to the Space Shuttle, Expendable Launch Vehicles (ELVs) are used to launch NASA spacecraft. These launch services are being procured from the private sector. NASA is committed to encouraging a healthy and expansive commercial space industry. As an example, NASA's nationwide network of 16 Centers for Commercial Development of Space represents a unique example of how Government, industry, and academic institutions can combine resources and talents to develop an industry-driven technology base in order to encourage and foster significant private sector investment and participation in commercial space ventures.

It is also important to continue to invest in measures which enhance the safety, reliability, and performance of the Shuttle system. The Advanced Solid Rocket Motor will incorporate changes in configuration, design details, and materials to meet more stringent design requirements and enhance safety margins and reliability. In addition, we expect a 12,000 pound increase in the delivery capability of the ASRM-equipped Shuttle. Funding is included in this budget request to continue the procurement of structural spares to replace those being used in the building of the new orbiter, Endeavour. The production of these spares will help maintain the capability to produce orbiters and significantly reduce the time to repair a damaged orbiter or build another, should the decision be made to do so. NASA is currently finalizing an agreement with Rockwell for the commercial provision of the hardware necessary to provide an extended duration orbiter capability. The hardware being developed under this program will allow the orbiter to stay in orbit up to 16 days. This capability is targeted to support the flight of USML-1 in FY 1992.

The current Space Shuttle fleet provides a base for our current requirements of transporting people and payloads to low-Earth orbit. A key issue for conducting human exploration missions is how large amounts of cargo can be transported to Earth orbit in the most cost-effective manner possible. Preliminary studies indicate that a significant increase in the lift capability to low-Earth orbit will be required. In the Advanced Launch Systems program, NASA and the Department of Defense have been working closely together on the advanced cost-effective technologies required to meet the future needs of both agencies. NASA also has studies under way, through FY 1990, on the Shuttle-C, an unmanned heavy-lift vehicle derived from Shuttle components. Beginning in FY 1991, NASA will consolidate all of these activities under the Advanced Transportation Technology program. Funding is included in FY 1991 to expand this program to pursue definition activities of heavy-lift vehicle concepts to support Lunar and Mars missions and expand NASA development of a low-cost advanced main engine propulsion system.

Space Station Freedom is the cornerstone of our space program in the 1990's and beyond. It will be a facility for the conduct of research and technology development that is enabled or greatly enhanced by the presence of humans in space. It will contain attachments for the mounting of telescopes and other scientific instruments and it will encourage the development of robotic technologies to aid the crews in maintenance, repair, and replacement. Although the management of the U.S. polar platform has been transferred to the Office of Space Science and Applications, the U.S. polar platform and the European polar platform continue to contribute directly to the Space Station Freedom on-orbit

operating concept and remain fully subject to our international agreements with Europe, Japan and Canada. By providing the opportunity to spend long periods of time in space, the Space Station will be a testbed for the development of technologies for human exploration of the Moon and Mars. It could also be evolved into a transportation hub for the exploration of space.

This is a critical time for the Space Station. The program is transitioning from the preliminary design to the fabrication and testing of development hardware. A major review of the program, conducted in the last half of 1989 with U.S. users and our international partners, resulted in a rephasing of the program while preserving the same basic configuration and capabilities. All major contractors are on board, as are many of the subcontractors. The NASA program organization has been strengthened. All are looking forward to continuing the momentum of the effort.

The NASA Ground and Space Communications Networks provide the vital spacecraft operations, tracking, telemetry, command, data acquisition, communications, and data processing to meet the requirements of all NASA flight projects. This is accomplished through the use of a network of NASA ground stations and by three Tracking and Data Relay Satellite (TDRS) spacecraft working with a highly specialized ground station. This budget request continues development funding for a second Tracking and Data Relay Satellite System (TDRSS) ground terminal, additional TDRS spacecraft, and final definition studies of an Advanced TDRSS to extend network service into the 21st century and accommodate the future mission requirements projected for this era.

NASA's unique facilities and technical expertise are the underpinning for the successful accomplishment of the Nation's aeronautics and space programs. We cannot be leaders in space exploration without a first-class institutional capability.

Eighty-five percent of our research and development and operational funding goes to private sector contractors. We must have an in-house workforce that is technically at the forefront to be able to effectively monitor and direct these efforts and understand the details of the technology and science to be accomplished. The FY 1991 budget request contains an increase in the number of civil servants who are urgently needed to meet the increased workload associated with the Earth Observing System program, the Space Station Freedom program, and to enhance the capability of the workforce.

The need for first-class facilities is also key to maintaining our Nation's leadership position. The research laboratories, computing capabilities, aeronautical facilities, Space Shuttle launch facilities, rocket test stands, and deep space tracking stations of NASA are unique national resources. The NASA wind tunnels are used not only by NASA but are also depended on heavily by Department of Defense and the U.S. aerospace industry. They are key to developments in the aerospace industry, making the industry more competitive. The agency is currently in the third year of a five-year revitalization program to modernize NASA's major wind tunnels. This program has been formulated to restore NASA's aeronautical research and development facilities for productive use for the next decade and into the 21st century. The Numerical Aerodynamic Simulator is a preeminent computing capability required to obtain solution of complex aircraft design geometries which are currently intractable. All these facilities must be maintained to protect the huge investment the Nation has made in them. The repair, rehabilitation, and modernization of NASA's facilities is a high priority of the FY 1991 budget request.

SUMMATION

Mr. Chairman, this proposed budget is unique for several reasons. First, the budget has been formulated upon a foundation of a series of highly successful Space Shuttle and space science missions. With the transition to fabrication of Space Station Freedom, the initiation of an ambitious effort in Mission to Planet Earth, and the undertaking of a technology program to enable human exploration beyond Earth orbit, the NASA program has assumed a broader and more complex dimension. As a result, we now find ourselves at the boundaries of three new frontiers. One is the frontier of scientific understanding of our universe, our solar system, and our own planet. Another is the frontier of technology for the next century -- the ability to do reliably, safely, and economically everything that the challenges of space demand. And the third is the frontier of the human spirit which will be crossed when humans are able to live and work on other planets.

The proposed FY 1991 budget demonstrates concretely the President's commitment to provide the resources required to advance these frontiers and to establish a robust American presence in space. While the resources required represent an increase over prior fiscal years, the dominant portion of those resources are needed to support the ongoing program previously approved by the Congress. However, as I have

stated, the total program enabled by these resources represents an investment in America for both the near term and for future generations, and, I believe, merits the full dollar investment reflected in the President's request. I seek your support, Mr. Chairman, and the support of this Committee, in obtaining Congressional approval of the $15.1 billion program as outlined in NASA's budget submission.

Mr. Chairman this concludes my prepared remarks. I would be pleased to respond to your questions and those of other Members of the Subcommittee.

National Aeronautics and Space Administration

Hold for Release Until Presented by Witness

March 13, 1990

Subcommittee on Transportation, Aviation and Materials

Committee on Science, Space and Technology

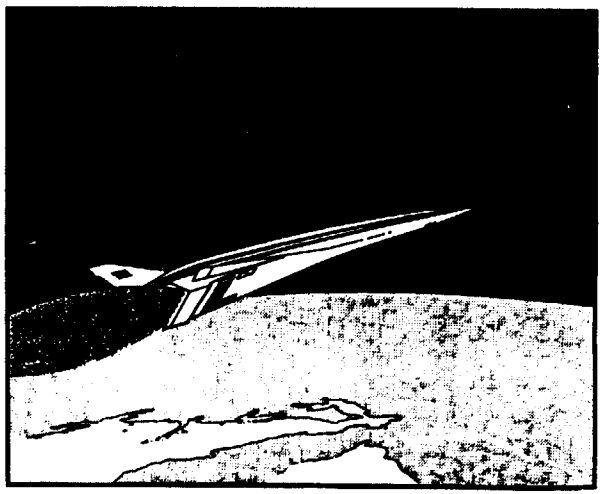
Subcommittee on Research and Development

Committee on Armed Services

House of Representatives

Statement by:

J.R. Thompson
Deputy Administrator
National Aeronautics and Space Administration



101st Congress

STATEMENT
OF
Mr. J. R. THOMPSON
DEPUTY ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Transportation, Aviation and Materials
Committee on Science, Space, and Technology

and the

Subcommittee on Research and Development
Committee on Armed Services

House of Representatives

Mr. Chairmen and Members of the Subcommittees:

I am pleased to join with my DoD colleagues to review progress and plans for the National Aero-Space Plane (NASP) program.

NASP is a technically demanding technology program, essential to the future of the United States. NASP is important because it advances technology in key fields such as propulsion, materials, structures and computational sciences whose application, though critical to future aerospace vehicles, extends beyond aerospace into other U.S. industries. NASP is important because, as launch vehicles and Airbus demonstrate, aerospace is an internationally competitive endeavor where U.S. preeminence is under direct challenge. That both Europe and Japan (and perhaps the U.S.S.R.) are pursuing hypersonic vehicles should not go unnoticed. Finally, NASP is important because it points to the future, stating clearly that the hypersonic vehicles we fly in both the civil and military sectors in the 21st Century will be designed and built in the U.S.

In times when Federal expenditures must be held down, long-term investments in technology such as NASP make tempting targets for budgetary reductions. I believe any such cuts would be genuinely damaging. The harm would come not immediately but, in the next two decades as our country works to maintain its competitive technical edge in world markets.

NASP is now soundly based. Well structured, with industry and government working together, with progress both substantial and documented, NASP is a program we need, one that deserves, indeed requires your support.

In my remaining remarks, I will present NASA's FY 1991 Transatmospheric Research and Technology budget request, comment on programmatic status, and review the technical progress including NASA's role in it.

The NASA budget request for NASP in FY 1991 is $119M in Transatmospheric Research and Technology. This is consistent with the recommendation made by the National Space Council in its July 1989 report on NASP. The request represents the required level of funding to support the crucial propulsion system and airframe analyses and testing leading to the X-30 decision. In addition to its direct funding support to the program, NASA also provides substantial and vital institutional support made up of technical specialists, wind tunnel and propulsion test facilities and supercomputers.

The National Space Council review last summer led to many significant improvements in the program and, as a consequence, it has benefited by being stronger now than ever. Both NASA and Air Force management have reaffirmed their whole-hearted commitment to the program. The Steering Group, which is chaired by the Under Secretary of Defense for Acquisition, now has the NASA Deputy Administrator as the Vice Chairman, with the Associate Administrator for NASA's Office of Aeronautics, Exploration and Technology (OAET) remaining as a key member. An indepth Quarterly Technical Review process has been initiated which involves the NASA Deputy Administrator, Associate Administrator for OAET, the three NASA Research Center Directors, the Air Force Under Secretary for Acquisition and DoD Laboratory Directors. We believe this process will be

extremely valuable in keeping the program on track and in keeping senior management close to the technical and programmatic status.

On the contractor side, there has been a major commitment to a unique teaming arrangement whereby all five competing contractors can now participate together, with full cooperation, toward the common objective of a viable X-30. The benefits of teaming include eliminating duplication of effort and the accelerating pace and synergisms resulting from technology sharing within a single team. Also, Government researchers will be able to contribute directly rather than through "generic" data as required by competition. The contractors are able to remain open to the benefits of technology spinoffs and still be genuine competitors on future NASP-derived concepts. NASP is probably the ideal program for such a bold contractual approach because of the challenge of the vehicle and the fact that each contractor has excellent ideas, concepts and expertise. All contractors have recognized these many benefits and enthusiastically support this teaming plan. I believe that the commitment of a new Steering Group and senior agency management, and the new contractor team, give the NASP program a much stronger and more cohesive posture for the remainder of the current technology phase --Phase II-- and beyond.

At its Fall meeting, the Steering Group strongly recommitted to the single-stage-to-orbit goal for the program. An incremental approach to the X-30 is being pursued in which a robust design philosophy allows upgrades in components and subsystems to be incorporated into any future vehicle as advances in technology continue. The contractor teaming allows all of these efforts to be highly focused toward the eventual optimized configuration.

Technical progress is being made on all fronts. The technical status continues to be quite impressive and appropriate to the current schedule. For example, both Pratt and Whitney and Rocketdyne have conducted "large-scale" tests of engine combustor hardware up to Mach 8 conditions, and both have tested subscale propulsion module tests in the speed range of Mach 4 to 8. Levels of performance have been achieved which give confidence that the necessary values can be achieved at these conditions. Evaluation of the "large-scale" total propulsion system package, including transitions of engine operating mode, remains a challenge, as does generation of sufficient data in the very high Mach number regime.

Work in materials and structures has demonstrated significant progress toward high-temperature performance at very light weights. Representative, large-scale structures have been built from advanced materials such as titanium-aluminides and carbon-carbon composites. The greatest challenges remain in demonstrating scale-up of these structures to appropriate aircraft panels and in actively-cooled structures which are required in high heat flow areas such as engines. Compatibility of new materials with hydrogen is also a remaining issue.

Aerodynamic technology is also advancing. There is a substantial data base on a variety of configurations, and current computational fluid dynamics tools are achieving good correlation with existing data. Methods are still being evolved for predicting mixing (and hence combustion efficiency) in engine flows and for determining transition from laminar to turbulent flow. The latter is important for predicting local aerodynamic heating and engine-inlet flow.

NASA has been a prime contributor to the progress to date. More than 300 civil service employees at the Langley, Lewis, and Ames Research Centers are committed to NASP. Many of these are the same technical specialists who maintained the national expertise in hypersonics in the years prior to NASP and are, therefore, heavily relied upon for oversight and consulting as well as the conduct of technical tasks. Wind tunnel tests of many competing aircraft configurations covering the speed range from takeoff to Mach 20 have been conducted in NASA facilities. Conventional force, moment and pressure measurements have been made, but also special issues such as ground-effect on landing and takeoff (in Langley's 14' x 22' Tunnel) have been investigated. The subscale engine module tests, which have been so important to the propulsion contractors, are still being conducted in Langley's two supersonic combustion ramjet (scramjet) test facilities, and the Lewis Research Center has taken the lead for the program in the area of slush hydrogen. The Numerical Aerodynamic Simulator at Ames, the Nation's premier supercomputing facility, has continued to be heavily committed, at about 30 percent of its capacity, to NASP. Class VI computers at other centers are also being used. In fact, the NASP program has pushed the application of advanced computational techniques to levels far exceeding any other program, and the full capability of our computers has been taxed at times.

NASA is strongly behind NASP. We are convinced that this program is crucial to U.S. aerospace preeminence and represents the very best in high-technology government/industry teamwork. It is a strong, soundly-based program, and NASA is proud to join with the DoD in this national effort in aerospace leadership.

Thank you, Mr. Chairmen.

NASA
National Aeronautics and Space Administration

Hold for Release Until Presented by Witness

May 3, 1990

Subcommittee on Science, Technology and Space

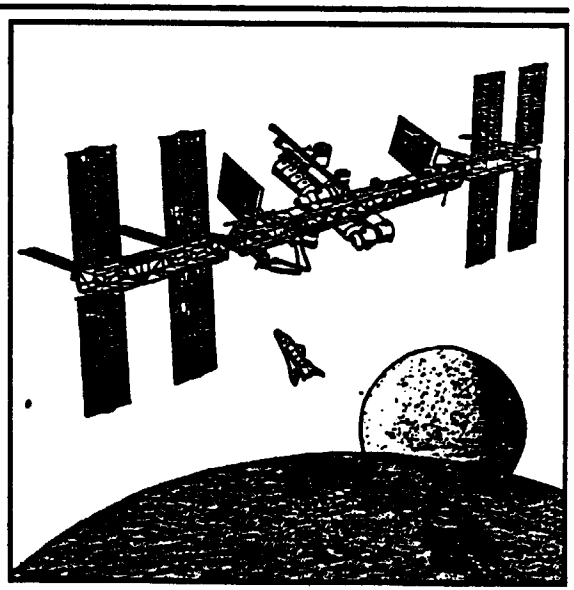
Committee on Commerce, Science and Transportation

United States Senate

Statement by:

ARNOLD D. ALDRICH

Associate Administrator
Office of Aeronautics,
Exploration and Technology



101st Congress

Statement of

Arnold D. Aldrich
Associate Administrator for
Aeronautics, Exploration and Technology

before the

Subcommittee on Science, Technology and Space
Committee on Commerce, Science and Transportation
U.S. Senate

Mr. Chairman and Members of the Subcommittee:

This is my first appearance before the Subcommittee as Associate Administrator for NASA's new Office of Aeronautics, Exploration and Technology (OAET). Earlier this year, NASA's Administrator, Admiral Richard H. Truly, asked that I provide a plan for merging the Office of Aeronautics and Space Technology (OAST) and the Office of Exploration (OEXP). The Administrator subsequently approved the recommended merger plan resulting in the establishment of OAET, which enables two closely related tasks, the definition of and planning for the Space Exploration Initiative (SEI) and identification and development of the new technologies required for SEI, to be fully integrated and to benefit from a focused management structure. The new organization continues to emphasize NASA's critically important aeronautics research and technology program and our commitment to advance technologies for current and future space missions, while pursuing exploration planning in a cohesive, strategic fashion.

As Associate Administrator, I am responsible for four major program areas and three of the NASA field centers. The centers are the Langley Research Center in Hampton, Virginia; the Lewis Research Center in Cleveland, Ohio; and the Ames Research Center at Moffett Field, California, which includes the Dryden Flight Research Facility at Edwards Air Force Base, California. While today's testimony will concentrate on program areas, I want to emphasize the importance of these four installations with a civil service staff of 7,999 full-time equivalents and a current research facility replacement value of $5.9 billion. As world-class research institutions, these centers constitute unique and extraordinary national resources. They consist of facilities and people whose work helps assure the United States remains preeminent in aeronautics and astronautics. OAET also supports critical Space Research and Technology programs at the other NASA field centers, including Johnson Space Center in Houston, Texas; Goddard Space Flight Center in Greenbelt, Maryland; Marshall Space Flight Center in Huntsville, Alabama; Kennedy Space Center in Florida; and the Jet Propulsion Laboratory in Pasadena, California. The Space Exploration Initiative and NASA's Space Research and Technology program will involve broad and active participation by all of the NASA field centers.

I am pleased to present NASA's FY 1991 Aeronautics, Transatmospheric, Space Research and Technology (R&T) and Exploration Mission Studies budget requests. With the critical investments proposed in this budget request, we can look forward to an exciting future in both aeronautics and space. For FY 1991, NASA is requesting $512.0 million for Aeronautics R&T; $119.0 million for Transatmospheric R&T; $495.9 million for Space R&T, which includes $179.4 million for the Exploration Technology Program; and $37.0 million for Exploration Mission Studies.

AERONAUTICS

The Aeronautics Research and Technology budget request supports a program constructed to strengthen the United States' leadership in aeronautics. It provides for a foundation of advanced technology upon which our industry can build to maintain our competitive posture in global aviation markets in the future. Of the total Aeronautics request of $512.0 million, $353.4 million is for the R&T Base and $158.6 million is for Systems Technology.

This month marks the 75th anniversary of the founding of NASA's predecessor, the National Advisory Committee for Aeronautics (NACA), and the birth of this nation's commitment to preeminence in aviation. Since the establishment of NACA in 1915, through the formation of NASA in 1958, and into the 1990's, our aeronautics program has represented an important technological resource within the United States, broadly contributing to both civil and military aviation. These 75 years have forged a strong partnership with industry and academia which has been the foundation for major aviation advancements and which still serves today as the model for cooperation in other fields. Today, the United States is the world leader in aviation. Our aeronautical products continue to provide the largest positive contribution to our country's trade balance and our aircraft are superior in performance and reliability. But our leadership is being challenged today as never before.

Strong foreign competitors are capturing an increasing share of important worldwide aviation markets. These competitors recognize the importance of advanced technology as a competitive factor and are committed to continuing the aggressive investments required to maintain their momentum in aeronautical research and development.

In addition, there is a continuing need to maintain the productivity and safety of our national air transportation system. Passenger revenue miles have tripled since 1970 and are expected to double again by the year 2000, further straining airport capacity and increasing the frequency of costly and annoying delays. And, aircraft themselves are a growing concern, as U.S. airlines enter the 1990's on the wings of the oldest civilian fleet in history.

NASA, with its industry and university partners, has worked to provide the technology instrumental in maintaining aeronautical preeminence. Through this close relationship with industry and the users of its products, we understand the

technological advances required to keep the United States in front, and we have taken steps to reorient our program to keep abreast of changing times. However, there is more that can be done to assure continued United States leadership in aeronautics.

Both the emerging challenge of foreign competition to the Nation's aeronautics industry and the tremendous opportunities open for technological advances and leadership were identified by the Office of Science and Technology Policy (OSTP) report entitled National Aeronautical R&D Goals: Technology for America's Future. A second OSTP report, National Aeronautical R&D Goals: Agenda for Achievement, updated the competitive situation and provided a detailed eight-point action plan for coordinating the efforts of industry, academia, and the government to ensure that U.S. industry remains a viable competitor in the world aviation marketplace. Together these reports outlined national goals in the transatmospheric, supersonic and subsonic flight regimes to focus high-leverage technology developments, and concluded with a broad strategy for revitalizing the Nation's capacities for innovation in aeronautical research and technology.

NASA's strategy for aeronautics research and technology represents a vigorous, but appropriate, response to the overall aviation environment within the context of the above-mentioned national goals and action plan. Our programs continue to emphasize high-payoff emerging technologies, to ensure the health and productivity of unique laboratories and facilities and to address critical barriers to the introduction of new technologies and aircraft concepts. To implement this strategy we are pursuing six key thrusts:

- Subsonic Transports - develop high-leverage technologies to ensure future competitiveness of U.S. subsonic aircraft and to enhance the safety and productivity of the National Airspace System

- High-Speed Civil Transports - resolve the critical environmental issues and establish the technology foundation for future decisions on economical, high-speed air transportation

- High-Performance Aircraft - provide technology options for revolutionary new capabilities in future high-performance fixed and rotary wing aircraft

- Hypersonics/Transatmospherics - develop critical technologies to support the development of future hypersonic and transatmospheric vehicles

- Fundamental Technology Base - pioneer the development of the fundamental knowledge base for the design and operation of advanced aerospace systems

- Critical National Facilities - develop, maintain and operate critical national facilities for aeronautical research and for support of industry, DOD, and other NASA programs

NASA has formulated an agenda in line with these six strategic thrusts to methodically address overall national needs in aeronautics. The FY 1991 budget

request supports this agenda with particular emphasis on addressing environmental issues associated with high-speed transportation, developing advanced composite materials technology for future airframes and engines, strengthening NASA/FAA cooperation in addressing congestion and air safety, and maintaining our commitment to a strong national facility capability.

In line with our first thrust in Subsonic Transports, our FY 1991 program reflects research leading to advances in aircraft flight systems, aerodynamics, and propulsion that can combine to offer efficient subsonic transports operating in a safe and productive National Airspace System.

To further enhance the safety and capacity of the National Airspace System, we have strengthened our cooperation with the FAA and renewed our research and technology effort dedicated to developing long-term technology solutions to support the FAA in addressing aviation safety, aging aircraft and congestion. An agreement between the FAA and NASA was signed by the respective Administrators in January 1990 which formally reconstituted the FAA-NASA Coordinating Committee and outlined a top-level framework for cooperation composed of six major areas of focus: Human Factors, Severe Weather, Environmental Compatibility, Cockpit/Air Traffic Control (ATC) Integration, Airworthiness and Program Support. Ongoing and new cooperative research and development activities will be jointly pursued in these program areas.

Cooperative NASA-FAA efforts continue to produce excellent results that are contributing directly to safety and efficiency in the National Airspace System. A unique Engine Monitoring and Control System (E-MACS) display has been developed which allows pilots to quickly assess the performance and status of the aircraft's engines during high pilot workload situations such as takeoff and landing. Significant improvements over conventional display systems in detecting engine faults or abnormalities have been demonstrated. Research on the detection and avoidance of severe windshear hazards during terminal area operations has resulted in a new windshear hazard index. This index, which directly indicates the effect of windshear on aircraft performance, has received wide industry interest. Continuing cooperative research in this area focuses on in-flight windshear detection sensors and flight management concepts to reduce the risk associated with windshear encounters. Cooperative research focused on FAA and airline operators' concerns about aging aircraft are being addressed through the development of Non-Destructive Evaluation (NDE) techniques capable of scanning large sections of aircraft structures for fatigue and corrosion damage. A thermal imaging NDE system is currently being developed for demonstration.

Advanced turboprops offer potential for significant gains for subsonic transport aircraft; however, a concern remains about noise observed on the ground from aircraft flying at cruise condition. NASA, in cooperation with the FAA, employed the Propfan Test Assessment (PTA) aircraft to obtain a unique data base for enroute noise. These ground noise measurements provide the basis for understanding source noise propagation to ground level and its variations due to atmospheric conditions. The data are now being analyzed to help develop and verify the advanced, analytical prediction codes for future design application. This

concludes the large-scale flight testing element of the Advanced Turboprop Program and establishes a data base for design of future turboprop powered aircraft.

Advances in materials and structures technology provide major opportunities for improvements in performance of subsonic aircraft through reduced airframe structural weight and higher temperature propulsion systems. Our Advanced Composite Materials Technology Program activities include development of organic polymers for high-temperature, toughened thermoset and easily processible thermoplastic composites for future airframe structures. These materials are being incorporated in advanced structural concepts to identify opportunities for reducing composites fabrication cost using advanced processes. A new composite fabrication concept, known as Resin Transfer Molding (RTM), has been developed which can reduce production costs up to 25 percent and weight by 40 percent relative to current aluminum airframe structures. This process uses low-cost composite materials and can be automated to further reduce manufacturing cost. The RTM concept was demonstrated in FY 1990 by fabricating a large stiffened panel representative of a wing element with the strength and damage tolerance required for commercial applications. In FY 1991 program efforts will be increased to design, fabricate and test larger scale subcomponents to verify innovative, low-cost composite structures technology which is applicable to aircraft wings and fuselages. The initial verification of composite design and analysis methods for these large-scale structural components will provide a baseline for future development of full-scale composite structures.

Our Advanced High Temperature Engine Materials Technology Program focuses on providing revolutionary composite materials and structural analysis techniques for 21st century subsonic transport engines. Composites have been fabricated which maintain strength and toughness after thermal cycling from room temperature to 1100 degrees Centigrade for over 500 cycles, an environment which is characteristic of that experienced by jet engine compressors and turbines.

Our thrust in High-Speed Civil Transports is addressed primarily through the High-Speed Research (HSR) Program we initiated in FY 1990. As planned, we are significantly increasing our efforts in this program which was directed at critical environmental compatibility issues and establishment of a foundation for subsequent decisions on future high-speed civil transport technology and development programs.

International air travel is an integral part of today's global marketplace. While subsonic transports will continue to be an important market segment, high-speed aircraft will likely be the next plateau of competition in the international aviation arena. Currently, however, three critical environmental concerns: atmospheric impact, airport noise, and sonic boom, present powerful private sector disincentives. The HSR Program focuses on each of these concerns. It builds on NASA's extensive efforts in upper atmospheric research and previous experience in airport noise and sonic boom reduction technology to resolve these three barrier environmental issues and to develop the basis for evaluating technology advances that can provide the necessary environmental compatibility. Resolution of these critical environmental

issues will place the U.S. in a position to make informed decisions on high-speed aircraft technology development in the future.

The first HSR element, atmospheric impact, involves two research efforts: long-term atmospheric chemistry assessment and low emission combustion research. A committee of eminent scientists from NASA's Upper Atmosphere Research Program is guiding the study of the possible long term effects of high-speed civil transport aircraft operation on atmospheric chemistry and climatology, with special emphasis on ozone. Twenty grants and contracts are being sponsored in the current fiscal year to develop improved computer-based models of the lower stratosphere and tropopause, examine nitrogen oxide (NOx)/ozone chemistry in the laboratory, and begin planning for in-flight experiments. In FY 1991, we will expand the scientific community involvement and intensify the global atmospheric assessment activity. In parallel with this effort, we are conducting low emission combustion research involving the development and test of alternative methods for reducing or eliminating engine exhaust products that cause ozone depletion. The primary focus is to develop advanced technology combustor designs which produce very low amounts of NOx emissions. In FY 1991, we will be emphasizing testing of experimental hardware in addition to analytical studies.

The second HSR element, noise reduction, involves research on alternative engine cycles and jet noise suppression aimed at providing the acoustic levels equal to those of today's quietest subsonic aircraft. Source noise research in FY 1991 will shift to increased screening of concepts that have the potential to meet reduction goals. Early results from wind tunnel experiments of advanced jet noise suppressors have shown promise, but considerable work will be required to achieve the desired noise levels.

The third HSR element, sonic boom reduction, includes aircraft configuration research aimed at reducing sonic boom levels and conducting human response evaluations to define criteria for acceptability. Airframe technologies that promise synergistic benefits for sonic boom, noise and emissions by reducing weight or improving aerodynamics are being studied. This work will transition to increased wind tunnel and flight research in FY 1991. High-lift and sonic boom wind tunnel models will be designed and fabricated for subsequent concept assessment and analysis validation. Supersonic laminar flow control experimental research will expand with completion of the F-16XL flight test evaluation of a passive glove and initial design of a wing leading edge with suction.

Our thrust in High-Performance Aircraft is focusing on providing a proven technology base to enable unprecedented levels of maneuverability and agility of fighter aircraft and to ready the technology base for supersonic STOVL aircraft and advanced rotorcraft.

NASA continues to cooperate with DOD to provide technology options to enable superior military aircraft. The High Angle-of-Attack Technology Program is a comprehensive aerodynamics, flight dynamics and control research program that is exploring the lower-speed, high angle-of-attack portions of the flight envelope that may provide tactical advantages through increased agility and maneuverability.

The program, which contains analytical, computational, wind tunnel, and flight research elements, was augmented in FY 1990 to expand validation to extremely high angles-of-attack. A detailed data base has been developed for the F/A-18 aircraft with conventional and advanced research control systems. A thrust vectoring control system for both pitch and yaw control will be installed and both computers and wind tunnels will be utilized to design forebody yaw control systems. Data, important for computational methods validation, have been obtained that enable comparisons of predicted and flight measured aerodynamic flow characteristics. In FY 1991 we will conduct flight evaluations of the enhanced maneuverability resulting from the thrust vectoring control system.

Full-scale tests of the E-7A supersonic Short Takeoff and Vertical Landing (STOVL) fighter successfully validated ejector/augmentor performance required for hover and low-speed flight. This cooperative STOVL research and technology program is jointly funded by NASA, DARPA, and the Department of Industry, Science and Technology of Canada. The full-scale powered model of an E-7A aircraft was tested in both the 40- by 80-foot and 80- by 120-foot test sections of the National Full-Scale Aerodynamics Complex (NFAC) at Ames Research Center. Aerodynamic performance of the de Havilland designed ejector on the full-scale aircraft was very good, achieving an augmentation ratio of 1.58, the highest full-scale aircraft augmentation to date. The U.S./U.K. ASTOVL program is continuing to jointly develop a common technology set including controls, nozzles, hot gas ingestion, ducts and valves, and ground erosion.

The Rotorcraft research and technology program is primarily focused on high-speed configurations. Simulation experiments of tiltrotor configurations have shown advantages for enhanced maneuverability. Large-scale wind tunnel investigations have validated tiltrotor performance predictions. Small scale tests are also investigating the feasibility of advanced configurations. These studies are continuing to identify the technology needs of high-speed rotorcraft and will provide a framework for future rotorcraft research.

Our Hypersonics/Transatmospherics thrust is to develop critical technologies to support the development of future hypersonic and transatmospheric vehicles. NASA's primary focus is the National Aero-Space Plane (NASP) program, a major national effort to develop, and then demonstrate in flight, the most critical technologies to enable single-stage-to-orbit with airbreathing primary propulsion. This is complemented by a hypersonic research effort within the Aeronautics research and technology base program which stresses fundamental understanding of the controlling physical and chemical phenomena for hypersonic vehicles and engines. Specific issue areas include boundary layer transition at high Mach numbers, turbulent mixing and mixing enhancement, and very high-payoff metal-matrix composite materials. Advancing methodology for integrating technology disciplines is a significant emphasis.

Our Fundamental Technology Base thrust emphasizes fundamental research, cross-cutting technology development, and validation of numerical simulation techniques to maintain the theoretical, experimental and predictive foundation necessary to extend our aviation preeminence into the future. New and innovative

approaches combining advanced computer architectures, algorithms and software are being pursued to enhance our capabilities to simulate the complex behavior of aerodynamics, materials, structural mechanics and chemically reacting flows. We are working to mature critical numerical simulation for application to the design and analysis of aerospace vehicle components and to pioneer the technology base to enable the multidisciplinary design and simulation of complete vehicle and propulsion systems.

We continue to enhance the pathfinding capability of the Numerical Aerodynamic Simulation (NAS) system at Ames Research Center. We have upgraded the main memory capacity of High-Speed Processor-2 from 32 to 128 million words (this was the first installation of the new 128 million word version of the Cray Y-MP supercomputer) and we plan to replace our first high-speed processor with the next generation of supercomputers in FY 1991. The NAS continues to be used to pioneer new simulation capabilities over a broad range of aerospace applications including structural mechanics, aeroelasticity, turbo-machinery, rotorcraft and powered lift modeling, as well as Space Transportation System and National Aero-Space Plane support. During last year more than 1150 researchers, working on 460 projects, accessed NAS from 120 remote sites. Researchers accessing the NAS from our Langley Research Center developed a new highly efficient structural analysis code for application to the Space Shuttle solid rocket motor case. The method fully exploited the parallel and vector processing capabilities of the 8-processor Cray Y-MP to achieve a computational speed of 1.34 billion operations per second, one of the highest speeds ever accomplished, on a very large, 55,000 degree-of-freedom finite element analysis. Researchers developed the capability to simulate flows about realistic aerodynamic bodies in relative motion. This new capability has been used to simulate the separation of the Solid Rocket Boosters (SRB) from the Space Shuttle. The computational tool is applicable to a wide range of space flight applications, such as Space Shuttle, SRB and External Tank separation sequences, staging sequences of multistage launch vehicles, and the release sequence of the Pegasus satellite launch vehicle; and aeronautics applications, such as stores separation from high-performance aircraft and ground/aircraft interaction during takeoff and landing of STOVL aircraft.

As part of our work in computer science, we have increased our emphasis on research into innovative approaches to achieving significantly higher performance computing capabilities for single and multiple discipline simulations. We have developed and demonstrated new computational fluid dynamics algorithms and other aeronautics applications on massively parallel computers and have expanded our investigation of alternate architectures to include parallel computers implemented with the newest and most powerful Reduced Instruction Set Computer (RISC) based microprocessors. We are continuing to work actively with the other members of the government high-performance computing team to define NASA's role in the multi-agency High Performance Computing program.

Investments in propulsion technology continue to be a major pacing item in achieving improvements in aircraft system performance and the understanding of the complex flow inside an engine is the key to achieving further advances in propulsion technology. Researchers at Lewis Research Center recently completed

successful development of a multistage turbomachinery computer code which, for the first time, provides the capability to analyze complex three-dimensional flow fields, including secondary vortices caused by viscous effects. Using a modern supercomputer, this code, when applied to two full compressor stages, predicted the same flow choking phenomena seen in experiments and heretofore uncaptured by analytical methods. We are currently utilizing ongoing low-speed and high-speed turbomachinery experiments to further develop the computer model for improved accuracy and reduced computer time.

Our research program is placing strong emphasis on fundamental fluid physics and materials research, both of which will lead to the development of new and enabling technologies that will be key to aviation advances in the next century. Understanding of the basic physical nature of fluid flows remains key to the design of efficient aircraft and propulsion systems of all kinds. We are increasing our focus on obtaining a physical understanding of boundary layer transition and turbulence which is the major barrier to achieving a complete understanding of fluid physics. With this understanding we can develop and verify new powerful techniques for active control of boundary layer transition and turbulence over airframes, and within engine inlets and nozzles. The objective of our advanced materials program is to develop and validate the technology base to enable the broad use of advanced materials in future airframe and propulsion structures. Generation of a research data base will promote improvements in performance, safety, and durability of aircraft, as well as reduce weight and life cycle cost. The materials program continues to place a strong emphasis on developing basic understanding and technology relationships among processing parameters and material properties, including both monolithic and composite materials, with particular focus on high-temperature applications.

Finally, the Critical National Facilities thrust is addressed though an augmentation for maintenance of facilities, in addition to the five-year NASA Major Wind Tunnel Revitalization program which began in FY 1989.

NASA remains committed to, and supports, a strong national capability through unique facilities and technical expertise. We are the steward of the Nation's major Aeronautical test facilities. We have included in this request the third increment of the 5-year Major Wind Tunnel Revitalization Program. The Hypersonics complex at Langley Research Center and the 10x10 at Lewis Research Center are in the construction phase and are on schedule. The Ames Research Center 12-Foot Wind Tunnel design is complete and the site is ready for construction. The final designs of the FY 1990 projects are progressing well and expected to be ready for the start of construction this fiscal year. The FY 1991 plan will address the upgrade of five major tunnels located at Lewis and Langley Research Centers.

Our FY 1991 request includes a facilities maintenance augmentation. Over one-half of NASA's national facilities are thirty years of age and many are approaching fifty years of age. Historically, maintenance of our facilities has been underfunded to the point that their operational capability and productivity have been adversely affected. This augmentation is critical to correct this problem. It includes increased maintenance of cooling systems, auxiliary equipment and roofs; corrosion control of

major wind tunnels; and increased preventive maintenance on elements of facility power systems, heating, air conditioning, and other utility systems.

TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY

The NASA budget request in FY 1991 for the National Aero-Space Plane (NASP) program, a joint program with the Department of Defense (DoD), is $119 million in Transatmospheric Research and Technology. NASP is a technically demanding technology program, essential to the future of the United States. NASP is important because it advances technology in key fields such as propulsion, materials, structures and computational sciences whose application, though critical to future aerospace vehicles, extends beyond aerospace into other U.S. industries. NASP is important because, as launch vehicles and Airbus demonstrate, aerospace is an internationally competitive endeavor where U.S. preeminence is under direct challenge. That both Europe and Japan (and perhaps the U.S.S.R.) are pursuing hypersonic vehicles should not go unnoticed. Finally, NASP is important because it points to the future, stating clearly that the hypersonic vehicles we fly in both the civil and military sectors in the 21st Century will be designed and built in the U.S.

The NASA budget request for the NASP is consistent with the recommendation made by the National Space Council in its July 1989 report on NASP. The request represents the required level of funding to support the crucial propulsion system and airframe analyses and testing leading to the X-30 decision. In addition to its direct funding support to the program, NASA also provides substantial and vital institutional support made up of technical specialists, wind tunnel and propulsion test facilities and supercomputers.

The National Space Council review last summer led to many significant improvements in the program and, as a consequence, it has benefited by being stronger now than ever. Both NASA and Air Force management have reaffirmed their whole-hearted commitment to the program. The Steering Group, which is chaired by the Under Secretary of Defense for Acquisition, now has the NASA Deputy Administrator as the Vice Chairman, with the Associate Administrator for OAET remaining as a key member. An indepth Quarterly Technical Review process has been initiated which involves the NASA Deputy Administrator, Associate Administrator for OAET, the three NASA Research Center Directors, the Air Force Under Secretary for Acquisition and DoD Laboratory Directors. We believe this process will be extremely valuable in keeping the program on track and in keeping senior management close to the technical and programmatic status.

On the contractor side, there has been a major commitment to a unique teaming arrangement whereby all five competing contractors can now participate together, with full cooperation, toward the common objective of a viable X-30. The benefits of teaming include eliminating duplication of effort and the accelerating pace and synergisms resulting from technology sharing within a single team. Also, Government researchers will be able to contribute directly rather than through "generic" data as required by competition. The contractors are able to remain open to the benefits of technology spinoffs and still be genuine competitors on future

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Work in materials and structures has demonstrated significant progress toward high-temperature performance at very light weights. Representative, large-scale structures have been built from advanced materials such as titanium-aluminides and carbon-carbon composites. The greatest challenges remain in demonstrating scale-up of these structures to appropriate aircraft panels and in actively-cooled structures which are required in high heat flow areas such as engines. Compatibility of new materials with hydrogen is also a remaining issue.

Aerodynamic technology is also advancing. There is a substantial data base on a variety of configurations, and current computational fluid dynamics tools are achieving good correlation with existing data. Methods are still being evolved for predicting mixing (and hence combustion efficiency) in engine flows and for determining transition from laminar to turbulent flow. The latter is important for predicting local aerodynamic heating and engine-inlet flow.

NASA has been a prime contributor to the progress to date. More than 300 civil service employees at the Langley, Lewis, and Ames Research Centers are committed to NASP. Many of these are the same technical specialists who maintained the national expertise in hypersonics in the years prior to NASP and are, therefore, heavily relied upon for oversight and consulting as well as the conduct of technical tasks. Wind tunnel tests of many competing aircraft configurations covering the speed range from takeoff to Mach 20 have been conducted in NASA facilities. Conventional force, moment and pressure measurements have been made, but also special issues such as ground-effect on

landing and takeoff (in Langley's 14' x 22' Tunnel) have been investigated. The subscale engine module tests, which have been so important to the propulsion contractors, are still being conducted in Langley's two supersonic combustion ramjet (scramjet) test facilities, and the Lewis Research Center has taken the lead for the program in the area of slush hydrogen. The Numerical Aerodynamic Simulator at Ames, the Nation's premier supercomputing facility, has continued to be heavily committed, at about 30 percent of its capacity, to NASP. Class VI computers at other centers are also being used. In fact, the NASP program has pushed the application of advanced computational techniques to levels far exceeding any other program, and the full capability of our computers has been taxed at times.

SPACE RESEARCH AND TECHNOLOGY

Technology is an essential element of "investing in the future"-- a message that the President has sent along with this budget request to Congress. The FY 1991 request of $495.9 million represents a continued commitment to providing technology that enables and enhances future space missions.

Our technology program contributes significantly to space missions by increasing mission safety and reliability, reducing development and operations costs and enhancing mission performance and benefit. Further, it strengthens the Nation's aerospace capabilities by building strong partnerships with industry and the university community as well as revitalizing and expanding NASA's capabilities. Technology programs provide both stimulus and support to the education of the next generation of engineers and scientists.

Advancements in technology made possible the past achievements of the civil space program. The technologies developed for Apollo in areas such as propulsion and guidance, navigation, and control allowed our Nation to initiate our quest to explore other planetary bodies. NASA continued this tradition with the Space Shuttle Program where critical developments in thermal protection, propulsion and avionics enabled the development and operation of the manned reusable space vehicle which regularly performs a wide variety of important missions.

Technology developments in power, automation, robotics, and structures will enable us to build Space Station Freedom, a permanently manned facility in space, during the 1990's. Technology developments in sensors and power systems helped us learn more about our planet Earth and the solar system through such spacecraft as Seasat, Viking, and Voyager. Our technology efforts will continue to support the next generation of science missions and will be the foundation for success in the exploration and expansion of human presence throughout the solar system.

The Space Research and Technology strategy is to provide a balanced, multidisciplinary program necessary to meet the Nation's spacefaring needs and goals. It responds to the President's initiatives in space transportation, Space Station Freedom, space science research and solar system exploration including support to the Earth Observing System. The OAET technology program covers:

- Transportation - by providing technology for reliable transportation systems with high performance, predictable service life and dependable operations costs. These efforts will:
  - develop design improvements for Space Shuttle Main Engine (SSME) high pressure turbopump blades and bearings as well as development of sensing techniques to more accurately detect impending engine failures and permit early, safe shutdown.
  - increase safety, reliability, reusability and serviceability of the current Space Shuttle System and provide for expansion of its capabilities.
  - develop technology for engine turbopump and hydrostatic bearings which can significantly improve the efficiency and life of the Advanced Launch Systems (ALS) Engine, the space-based chemical transfer engine and future upgrades of the SSME.
  - enable advanced manned and unmanned launch systems and space transfer vehicles.
- Space Station - by providing technology for the current and evolutionary phases of the Space Station Freedom Program. These efforts will:
  - expand capability and reduce the life cycle cost of Space Station operations. OAET-supported technology products which will be incorporated into the initial Space Station Freedom include large flexible solar arrays, large area silicon cells and nickel-hydrogen batteries in the power system; and on-orbit erectable truss structures.
  - develop improvements in automation and expert systems which will free up valuable crew time by assisting in maintenance of the Space Station and in robotics to allow us to conduct more experiments outside the manned facility.
  - enhance capabilities as a testbed to conduct technology development and validation.
  - develop cryogenic fluid transfer experiments which will improve our understanding of how to handle propulsion fluids in space in order to support lunar and Mars transfer vehicle fueling and refueling.
  - enhance capability as a transportation node for the future Exploration program.
- Space Science - by providing technology for Space Science programs focused on the planet Earth, the solar system, and the universe. These efforts will:

- develop technology advances in a variety of areas including power systems and sensors which will enhance the benefit from science missions, such as the Earth Observing System, the Advanced X-ray Astrophysics Facility (AXAF), the Comet Rendezvous and Asteroid Flyby (CRAF)/Cassini missions, and the Space Infrared Telescope Facility (SIRTF).

- enhance science mission performance and information return and reduce costs through technology advancements.

- Exploration - by striving to define and pursue key technologies for future Exploration Missions, including those required for the establishment of an outpost on the Moon and exploration of the planet Mars. These efforts will:

  - develop new and innovative capabilities, including aerobraking, in-space vehicle refueling, planetary rovers, and advanced electrical power, propulsion, and closed-loop life support systems

  - enable us to explore the solar system using both robotic and human missions.

- Breakthrough - by pursuing advanced technological concepts which have the potential for major evolutionary or revolutionary applications. These efforts will:

  - stimulate and explore advanced high-risk, high payoff technologies that have the potential to revolutionize the approach to future programs. Examples include:

    - Superconductivity. Due to the huge potential payoff in weight, size, and operational flexibility, the first application of the dramatic advances in superconducting materials may be in electronics and power and propulsion systems for space applications. Studies and experimental efforts are underway to define these applications and to evaluate superconducting materials under space conditions.

    - the assessment of a concept for a revolutionary fuel cell power system which could use the atmosphere of the Mars environment as one of the reactants.

This budget request provides the resources necessary to implement a balanced technology program, one truly critical to realizing the agency's goals. The Space Research and Technology Program consists of four elements. The first, the Research and Technology Base program, supports core research in technical disciplines. The second, the Civil Space Technology Initiative, addresses research and technology to enhance near-term space missions. The third element is the In-Space Technology Experiments program. This supports the development and validation of technology in space. The fourth element, the Exploration Technology Program

(formerly Pathfinder) will lay the building blocks needed to expand human presence and activity into the solar system. Let me now highlight some of our accomplishments over the past year in these areas and point out what we intend to accomplish with the FY 1991 funds.

Research and Technology Base

The FY 1991 request for the R&T Base is $125.7 million. This will support core disciplinary research in aerothermodynamics, materials and structures, power and propulsion, life sciences, human factors, information systems, and other key space technology fields. Included in this request are funds for the University Space Engineering Research Center program which was initiated in 1988.

There were several major accomplishments in FY 1990--including the vast amount of unique data which we are obtaining from the Long Duration Exposure Facility (LDEF). The LDEF spacecraft was retrieved in January 1990 after five and a half years in space. The 57 experiments onboard and the spacecraft itself will provide invaluable information on the long-term effect of exposure to the space environment. We will be studying space debris and meteoroid impact effects as well as environmental and atomic oxygen effects on materials and coatings, thermal systems, electronics, and optics. The knowledge attained from LDEF will allow us to make significant strides in research in support of Space Station, Space Science and Exploration space system designs.

In FY 1991, we plan to emphasize critical research in fundamental disciplines that will provide technology for future Earth observing and exploration missions. This will include research in sensor cooler technology and infrared detectors. In addition, studies of fundamental chemical processes important to the understanding of physical-chemical systems for closed-loop life support will continue.

Civil Space Technology Initiative (CSTI)

The CSTI program was initiated in 1988 to advance technology beyond basic research in order to expand and enhance system and vehicle capabilities for near-term missions. CSTI takes critical technologies to the point that the user can confidently incorporate these new or expanded capabilities into relatively near-term NASA missions. In particular, CSTI focuses on providing technology for reliable and cost-effective access to, operations in, and science missions from Earth orbit.

The CSTI program has already produced significant accomplishments. For example, in support of the agency's requirements in transportation, the Earth-to-orbit research effort has developed increased turbopump bearing durability and resistance to stress corrosion cracking. This will contribute directly to the safety and serviceability of the Space Shuttle Main Engine (SSME). We have also installed a prototype optical plume anomaly detector system for evaluation in the technology testbed stand at the Marshall Space Flight Center. This system will allow detection of incipient failures in propulsion systems prior to engine failure thus enhancing information return and reducing hardware loss. In support of

Space Science, an expert system, developed as part of our artificial intelligence research efforts, was used during the Voyager encounter with Neptune last August. This system successfully detected anomalies in the telemetry, diagnosed possible causes and provided valuable information in identifying possible solutions.

However, as you are aware, this program was reduced by $20.7 million from our requested level in FY 1990. As a result, one of the important technology elements in the program, the booster research effort, was essentially terminated. We intend to support a modest amount of the highest priority basic research in this area utilizing funds in the R&T Base. In addition, because of the budget reduction, technology delivery dates and planned technical accomplishments were slipped and stretched out in other areas, including automation, robotics, Earth-to-orbit propulsion and the control of flexible structures.

Our FY 1991 request of $171.0 million will allow us to continue to provide new and enhanced capabilities to users for incorporation of new technologies into their missions. We intend to maintain support for Space Station applications through focused research in automation and robotics and control of structures, for space science missions through research in precision structures, high-rate data systems, and sensor technology, and for transportation safety and reliability through research in Earth-to-orbit propulsion. For solar system exploration missions, CSTI activities in high capacity power and aerobraking are focused on critical enabling technologies. The Aeroassist Flight Experiment will contribute to significantly reducing the mass of propellant needed to be launched into orbit for planetary missions through the development of aerobraking techniques. The high capacity power program is developing technology options to enhance the performance and power output of space nuclear power systems. These are highly important for large lunar base activities and critical for major missions to the planets.

Exploration Technology Program

As previously mentioned, we are requesting $179.4 million in FY 1991 for the Exploration Technology Program to meet the challenge of President Bush's new vision of space exploration. The Exploration Technology Program will pursue development of a wide range of critical technologies needed for the return to the Moon and human and robotic voyages to Mars. This program will involve technologists and engineers from the full spectrum of the U.S. aerospace community including NASA Centers, national laboratories, industrial firms, and universities.

The Exploration Technology Program represents a start--not of a program plan--but of a technology investment needed for future program decisions. With these funds, we will expand technology investments which will enable a variety of strategies for mission architectures. We will focus on technologies that can increase safety and reliability, reduce risks and costs, and enhance mission performance.

During the last several years numerous national studies have assessed the need for significant investments in technology for future Exploration missions. In response to these findings and as part of the National Space Policy, the Pathfinder Program was initiated in FY 1989. We have recently reassessed the present results of

Pathfinder and a wide range of technology challenges for the Space Exploration Initiative. We need to go beyond this initial analysis and the funds we have requested will enable us to do so.

The Exploration Technology Program for FY 1991 consists of the previously planned Pathfinder Program as a foundation with augmentation to address a broader range of critical enabling technologies. Key challenges in the augmented program include aerobraking, space-based engines, regenerative life support, space nuclear power, in-situ resource utilization, space nuclear propulsion and many others.

Although FY 1990 funding for exploration technology (Pathfinder) was reduced from our request, we have maintained critical inter-Center and industry teams and maintained contracts and interagency commitments. We are ready to move out quickly in support of the President's vision of a "long-range, continuing commitment" to exploration. We have continued an effective pace in the development of space nuclear power through the SP-100 program, an interagency research effort which includes the Department of Energy, Department of Defense, and NASA. We have also had exciting developments in a number of other areas including the planetary rover project at Carnegie Mellon University where a six-legged rover is being developed that will be able to safely traverse obstacles two meters tall, crevices two meters wide and areas with 40 degree slopes. A six-legged testbed assembly has been completed and it took its first steps in December.

Emphasis in implementing the Exploration Technology program in FY 1991 will be on critical technologies for both robotic and human exploration in seven key areas: space transportation, in-space operations, surface operations, human support, lunar and Mars Science, information systems and automation, nuclear propulsion, innovative technologies and systems analysis. Over the next several years, we will be developing a wide range of technologies for SEI, many of which benefit life on Earth. To look at just one example, establishing a permanent presence on another planetary surface requires the development of new power technologies and regenerative life support systems. These may well lead to new environmental monitoring and waste management systems and safer, more efficient power systems for use on Earth which can be of great benefit as we strive to preserve our fragile planet. We know that the Apollo program and subsequent NASA programs have resulted in many "spinoff" technologies -- many more will be generated by this long-term, continuing commitment to space.

In-Space Technology Experiments

An important element of the Space Research and Technology program is the In-Space Technology Experiments activity. We are requesting $19.8 million in FY 1991 to support this effort. The objective of this program is the development of flight experiments to test highly innovative technologies which require research, testing and validation in the space environment. Taking these experiments into space will enable us to understand basic phenomena, reduce the risk to potential users, and increase the rate of technology transfer to future space missions. The wealth of data obtained from the retrieval of the Long Duration Exposure Facility

(LDEF) clearly demonstrates the benefits of acquiring data from the actual space environment in addition to ground-based research.

This program is designed to provide opportunities for the private sector and university space engineering communities to conduct in-space experiments. It is a new program initiated last year but it has already elicited strong support. In response to solicitations for experiment proposals which we have sent to industry, universities, and our internal NASA engineers and technologists, we have received over 300 excellent proposals. The areas of proposed research include fluid behavior in microgravity environments; the use of robotics in space construction, servicing, and other in-space operations; and environmental effects on materials from long-term exposure to the space environment.

In FY 1991, we intend to continue development of fourteen experiments that were initiated through this program and to support development of additional experiments from proposals received from industry, universities and NASA engineers.

A significant benefit of NASA programs is the synergism between our activities and those of U.S. aerospace industry and educational institutions. An objective of the Space R&T program is to strengthen U.S. engineering and technical talent throughout the university and industrial communities through the establishment of a strong partnership in technology research and development.

In the process of implementing our space research and technology program, we have established several activities specifically designed to encourage university engineering research. These include the University Space Engineering Research Center Program which supports nine inter-disciplinary engineering research centers engaged in innovative research and technology, the Investigators Research Program which provides grants to fund innovative research concepts, and the University Advanced Space Design Program which funds advanced systems study courses at the senior and graduate level.

EXPLORATION

The President's FY 1991 budget request for NASA demonstrates his commitment to a bold and exciting future in space. We are requesting $179.4 million in FY 1991 for the Exploration Technology Program and $37 million for Exploration Mission Studies to meet the challenge of President Bush's new vision of space exploration. Speaking on the twentieth anniversary of the Apollo 11 Moon landing, President Bush gave America a goal in space, and a pathway to get there. He said:

> "In 1961, it took a crisis --the space race--to speed things up. Today we do not have a crisis. We have an opportunity. To seize this opportunity, I am not proposing a 10-year plan like Apollo. I am proposing a long-range, continuing commitment. First, for the coming decade--for the 1990's--Space Station Freedom-- our critical next step in all our space endeavors. And next--for the new century--back to the Moon. Back to the future. And this time, back to stay. And then--a journey into tomorrow--a journey to another planet--a manned mission to Mars."

The National Space Policy, developed by the National Space Council and signed by President Bush on November 2, 1989, updates and reaffirms U.S. goals and activities in space and provides a broad policy framework to guide future U.S. space activities. One of the goals stated in this policy is "to expand human presence and activity beyond Earth orbit into the solar system." The Space Exploration Initiative will fulfill this goal.

Moreover, the commitment to return to the Moon and journey to Mars is evidence that the American people retain the vision, courage, and skills essential to national well-being in the twenty-first century.

The reasons for undertaking the Space Exploration Initiative are compelling:

- To fulfill the human imperative to explore
- To enhance our understanding of life in the universe
- To gain knowledge about our planet's origin, evolution and global dynamics
- To improve this nation's technological competitiveness
- To continue America's journey into space.

As with our past space endeavors, we will reap great rewards by challenging ourselves to realize our dreams. We will increase our storehouse of knowledge about the planets, including our own, and about the nature of life itself. We will develop new technologies, many of which will have applications that will improve our lives on Earth. We will stimulate science and engineering education in this country by inspiring and motivating our young people. By pursuing our exploration goals, we will improve our competitive technological position in the world and bolster our national pride and international prestige. Each time we have gone to the frontier and beyond, we have brought back more than we hoped for. As we journey outward once again, we will bring back more than we can imagine.

This "long-term, continuing commitment" to excellence and achievement in space announced by President Bush requires a sustained, significant commitment of national resources. Instead of going and coming back as we did with Apollo, we are going to stay. This means developing the infrastructure to support a long-term future effort and carefully planning future missions while executing those nearer at hand. A steady budgetary commitment will enable NASA to fulfill its national missions: to continue making advances in aeronautics, proceed with our excellent space science work, keep the Space Shuttle flying safely, get Space Station Freedom up and operating, and meet the challenges of human exploration of the solar system.

NASA has been studying human space exploration since the early 1960's. Recently, a number of studies have provided a clearer vision of the U.S. future in space. In 1986, the National Commission on Space recommended a direction to advance the broader goals of twenty-first century America, "to lead the exploration and development of the space frontier, advancing science, technology, and enterprise and building institutions and systems that make accessible vast new resources and support human settlements beyond Earth orbit, from the highlands of the Moon to the plains of Mars." In her 1987 report to the NASA Administrator, "Leadership and America's Future in Space," Dr. Sally K. Ride laid out a strategy for U.S. leadership in space which culminates in the exploration of Mars by humans. In 1988, "Beyond Earth's Boundaries," the Office of Exploration's first report to the Administrator, provided the results of several case studies of possible pathways and strategies for human exploration of the solar system and identified the basic needs of these cases. These reports and studies laid the groundwork for the President's commitment to the Space Exploration Initiative.

The pathway defined by the President in his speech on July 20 will allow us to meet the goal of expanding human presence and activity in the solar system, with each step into space building on the previous one. The work we do on Space Station Freedom in the 1990's in life sciences, technology development and validation, and operations will provide experience and information essential for a permanent lunar outpost. Likewise, establishing a lunar outpost before sending humans to Mars is both prudent and of significant benefit. We will gain experience living and working on another planetary body which is relatively nearby while experiencing significantly less risk than an initial journey directly to Mars would entail while developing new technologies and operational procedures required for a planetary outpost. We will learn how to "live off the land," testing surface systems and using in-situ resources, in preparation for our journeys to Mars. We can do first-rate science on the Moon, particularly in geology and astronomy.

To proceed toward implementation of the President's goal, NASA carried out a 90-day study to provide preliminary information on the potential technologies, benefits and program architecture for space exploration. The five reference approaches examined in the report provided a database of current information and a foundation for current and future mission analysis work, as well as preliminary assessment of scientific opportunities presented by the Space Exploration Initiative and the technical trades that might be required.

The study identified several factors which directly impact program cost, regardless of reference approach used: mass to low-Earth orbit, technology payoffs, scale of lunar and Mars activity, availability of heavy-lift launch vehicles, nature of international participation, and funding stability. It also identified several critical technology challenges: closed loop life support systems, aerobraking, advanced space engines, surface nuclear power, in-situ resource utilization, and radiation protection. Although these technologies are critical, this list is by no means inclusive. There are additional technologies currently under development or planned for development which are absolutely essential for mission success.

Our work has just begun. We are continuing our mission studies and working to better define program elements and requirements. We are investing in new technologies and outlining an overall strategy for Space Exploration Initiative technology. In addition, we are supporting a number of outside reviews of our activities. As I will describe in more detail later, we are about to initiate an extensive outreach program to search for new ideas and new approaches to technology and mission concepts. We have identified a number of program areas within NASA which are essential for the ultimate success of the Space Exploration Initiative: Space Station Freedom, heavy-lift launch vehicles, robotic missions, life sciences research, technology development, science opportunities, and institutional requirements. I would like to briefly discuss each of these areas.

President Bush called Space Station Freedom "our critical next step in all our space endeavors." There we will perform extensive life sciences research and devise countermeasures for long-term microgravity and radiation exposure which are vital for long journeys to Mars. We will develop and validate the technologies we will use for future space missions and develop required operational procedures. Our studies also show that Space Station Freedom will very likely be necessary as a transportation node, where we will assemble, test, launch, recover, and turn around the space vehicles which we will use in our outward journeys. At the outset of the Space Station Freedom program, President Reagan stated that the facility would be international, useful for research, and permanently manned. NASA is committed to attaining these goals. This includes upholding our international agreements for Freedom and assuring its continued usefulness for research. OAET is working closely with the Space Station Freedom management to ensure Freedom's compatibility with these objectives and with future exploration requirements.

Heavy-lift launch vehicle development is another program area crucial to the Space Exploration Initiative. Our studies show that to establish a lunar outpost, an Earth-to-orbit lift capability of approximately 70 metric tons is required. This requirement increases to 140 metric tons for a Mars outpost. Vehicles currently being considered to meet these requirements include Shuttle-derived vehicles and the new Advanced Launch System (ALS). ALS is currently being defined in a joint effort by NASA and the Department of Defense. The design objectives of ALS --low cost per flight, high reliability, and high operability-- make it an attractive addition or alternative to Shuttle-derived vehicles. Vehicles of different sizes could be developed to meet the needs of lunar and/or Mars missions. Other options for space transportation may emerge as we continue our study efforts.

NASA is already planning for some of the robotic missions which are integral to the Space Exploration Initiative. Robotic missions serve a number of critical functions: determining suitable/desirable landing and outpost sites; providing design data for human mission elements; conducting science investigations; and developing the basis of science investigations for human explorers. Additional work planned by NASA's Office of Space Science and Applications (OSSA) for the Mars Observer in FY 1991 will allow more data to be retrieved in support of the Space Exploration Initiative. OSSA is also planning to begin Phase B of the Lunar Observer in FY 1991.

Life sciences research is particularly important for the Space Exploration Initiative, and we are working closely with OSSA which is responsible for NASA's life sciences program. To ensure that we can send humans to Mars confidently, research must be conducted in the following areas: effects of microgravity and countermeasures, radiation environment, medical care, life support, and behavior and performance. We will use Space Station Freedom, robotic missions, and eventually the lunar base to understand life sciences requirements in these areas and test methods to mitigate risks. Life sciences requirements must be understood early in the planning process since they can significantly affect vehicle and systems designs.

Major technology investments need to be made now to ensure success in these epic journeys. Some of these developments will reduce the mass required to be launched to low-Earth orbit and, therefore, associated time and money. Some are also indispensable for the establishment of relatively self-sufficient planetary outposts. Still other technologies are important because they could allow us to accomplish the goals of the Space Exploration Initiative better, safer, faster, and cheaper. We are currently working on a report requested by the Senate Appropriations Subcommittee on VA, HUD, and Independent Agencies on specific technologies needed to meet the development and operational requirements of the Space Exploration Initiative. We expect to issue this report this spring.

Taking advantage of the unique scientific opportunities presented by long-term occupation of lunar and Mars outposts requires significant planning both by NASA and the research community. Scientists in many disciplines, including solar physics, geology, biology, astrophysics, chemistry and space physics will find abundant opportunities for research and experimentation through the Space Exploration Initiative. A combination of robotic and manned missions will serve science well; robotic science missions will both perform vital and interesting science and serve as building blocks for the manned missions of the Initiative.

NASA's Office of Space Science and Applications (OSSA) has the responsibility for defining and, ultimately, implementing the scientific programs which will be an integral part of the Space Exploration Initiative. We are working closely with OSSA to ensure that accommodating scientific planning and requirements is a critical element of our technology and mission analysis efforts.

The FY 1991 request for Exploration Mission Studies is $37 million. We will use this funding to support a series of broad trade studies, missions studies, technology trades and analyses of science opportunities. Mission integration studies will be conducted in a variety of technical areas including: transportation, surface systems, power, propulsion, life support and robotics. The studies will be conducted in close coordination with our technology development efforts.

A variety of opportunities for international cooperation exist in both the robotic and manned portions of the Space Exploration Initiative. On March 30, 1990, the White House announced a strategy for exploring these opportunities. A dialogue focused on the conceptual possibilities for cooperation will be held with Europe, Canada, Japan, the Soviet Union and other nations as appropriate. The dialogue will be based on guidelines prepared by the National Space Council which are consistent

with the National Space Policy and take due account of U.S. national security, foreign policy, scientific, and economic interests. The National Space Council will ensure interagency coordination and review during development of international cooperation on the Initiative, and will provide recommendations to the President as appropriate.

As you can see, the Space Exploration Initiative is a broad, bold program for space leadership which spans the breadth of NASA's programs. Much of our current effort is directed toward integrating the efforts of the various programs in space science, space flight, and technology as well as identifying a strategy for future progress. Most of the $15 million we received in FY 1990 for exploration is being spent on continuing the mission studies which have been ongoing for the past two years. A more recently defined activity for FY 1990 and beyond, one which will require a great deal of dedication and effort, is an extensive outreach program.

In December 1989, Vice President Quayle sent a letter to Admiral Truly asking NASA to take the lead in searching for and screening the broadest possible range of ideas about different architectures, new systems concepts, promising new technologies, and innovative uses of existing technologies. We want to ensure that all reasonable conceptual alternatives are evaluated and that the breadth of America's innovative and creative potential is drawn upon for the benefit of the Initiative. NASA has worked with the National Space Council staff and others to develop an outreach program for accomplishing this goal. We are planning a variety of activities to cast the widest possible net for new and innovative ideas which will include the involvement of industry, other Federal agencies and research facilities, technical societies and associations, and the university community in addition to our own continuing internal mission concept studies, science planning, and technology development efforts. The specific implementation plan for these outreach activities is in the final stages of refinement and we hope to proceed with this process in the near future.

NASA CAPABILITY

The programs that have been described above are critically dependent on the NASA institution, that is, the facilities and manpower that are required to conduct, manage, and support NASA's research and technology efforts. Maintaining our leadership in aeronautics and space requires an investment in people, the core of our capability. This is particularly true given the extended life-cycle of technology advances. A skilled in-house workforce must be maintained to see these advances progress from concept to implementation. Private sector contracting has been used extensively, with success, but not without certain drawbacks inherent in a contractor workforce. Our success in satisfying the unique and changing needs of our technology depends on a continuing strong human resource capability.

Without this institutional support, the research and development program outlined here cannot be conducted. It is imperative that the Wind Tunnel Revitalization Program and our facility maintenance augmentation be fully supported. It is also critical that the other facility additions and the institutional funding in the

Construction of Facilities and Research and Program Management budgets be supported.

The breadth of our "long-term, continuing commitment" to human exploration of space through the Space Exploration Initiative will undoubtedly generate new institutional requirements for NASA and, perhaps, other agencies as well. Our current institution, both manpower and facilities, is sufficient to begin work on the Space Exploration Initiative. We will be emphasizing an appropriate balance between in-house and contracted capability as we proceed.

INVESTING IN THE FUTURE

Our FY 1991 budget request is a critical step in realizing an exciting and challenging future in aeronautics and space and in expanding the frontiers of the future for the benefit of all Americans. Investment in technology represents a long-term strategic commitment to ensuring U.S. leadership. Investment in aeronautics and space R&T has played a fundamental role in achieving a leading role in the past and is the key to preeminence in the future.

Leadership in aeronautics is very important to our international balance of trade and national security and to the safety and efficiency of our air transportation infrastructure. We have a NASA strategy for maintaining technology leadership and, while we have made substantial progress in the past, much remains to be done. In partnership with U.S. industry, other government agencies, and the university community, we have prepared a roadmap and have defined priorities. We are aware of the tight budget environment and have requested only those high-payoff programs that are critical and timely. In FY 1991, we must strengthen our stewardship of the Nation's major Aeronautical test facilities, aggressively pursue those barrier technology issues that will allow U.S. industry to make informed decisions on high-speed aircraft, develop long-term solutions to support a healthy National Airspace System, and continue to pioneer the broad fundamental knowledge and technology base critical to the design of all future advanced aeronautical systems.

The ongoing NASA aeronautics research and technology program is conducting pioneering research in emerging technologies, selectively conducting the highest payoff systems technology programs, and producing technologies that industry can incorporate into future products. The results of our current research will be a major factor in our country's future aeronautical leadership. For 75 years, we have provided much of the technology base that has enabled the United States to be the world leader in aviation, but our task is not done. Today our leadership is being challenged on many fronts. The question is not whether we can afford to take on these challenges. The question is whether we can afford not to.

NASA is strongly behind the National Aero-Space Plane program. We are convinced that this program is crucial to U.S. aerospace preeminence and that it represents the very best in high-technology government/industry teamwork. It is a strong, soundly-based program, and NASA is proud to join with the DoD in this national effort in aerospace leadership.

NASA's Space Research and Technology program is well balanced and focused on the technology needs to enable and enhance our national space goals. The program supports vital basic research in technical disciplines, is structured to significantly enhance our near-term space missions and will lay the building blocks that will be the foundation for our future missions in space. Further, this program strongly contributes to assuring American strength in science and engineering by directing high payoff technical studies, providing and operating excellent research facilities and by setting vigorous and compelling technical goals and opportunities.

A key to future U.S. space leadership is the Space Exploration Initiative. Considerable preliminary planning is required to more fully understand the tasks ahead. Key technology programs are critical to success and require initial investment now. Vehicles and surface systems for these missions cannot be built until life sciences requirements are understood. No focused program plan has yet been agreed to, but now is the time to provide the initial resources to enable such a plan to be defined. The FY 1991 budget thus is an exciting opportunity to set our course as a spacefaring nation.

Thank you, Mr. Chairman. This concludes my prepared statement. I will be happy to answer any questions you may have.

NASA
National Aeronautics and Space Administration

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May 10, 1990

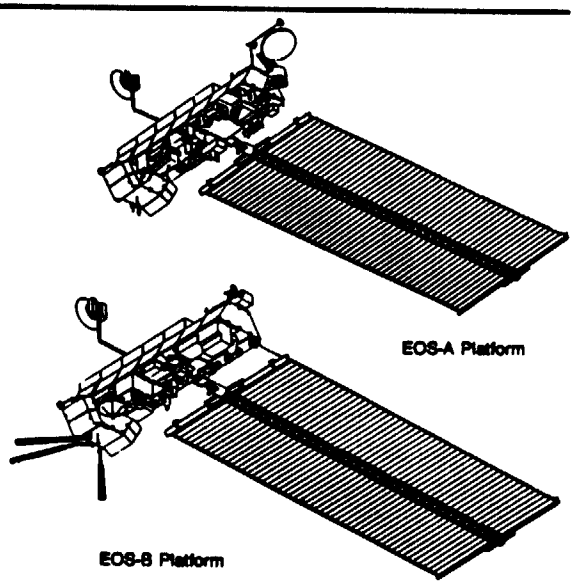
Subcommittee on Science, Technology and Space

Committee on Commerce, Science and Transportation

United States Senate

Statement by:

Dr. Lennard A. Fisk
Associate Administrator for
Space Science and Applications



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Statement of

Dr. Lennard A. Fisk
Associate Administrator for
Space Science and Applications

National Aeronautics and Space Administration

before the

Subcommittee on Science, Technology and Space
Committee on Commerce, Science and Transportation
United States Senate

May 10, 1990

Mr. Chairman and Members of the Subcommittee:

I am very pleased to have the opportunity to appear before the Committee.

When I appeared before you for last year's authorization hearing, the United States had not launched a major space science mission in more than five years, or a mission to the planets in more than a decade. Today, Magellan is enroute to Venus and Galileo to Jupiter. The Hubble Space Telescope will open a new window on the universe, and is undergoing its science verification and testing phase in preparation for its fully operational phase as a research facility in space. Seven additional Space Science missions are scheduled for this year alone. This launch rate will continue year after year into the next century. We have crossed over the horizon into a new era in Space Science, into a second golden age. We will, in the next few years, expand our knowledge of the universe in which we live more rapidly than at any time in human history.

As we enjoy the excitement of this second golden age of space science, however, we need to be concerned about the future of the human species. We live in a unique time, where human actions may be affecting the environment on a global scale. The impact of these human activities is uncertain. It is time to reduce the uncertainty by developing sufficient knowledge of how the Earth works, and what we are doing to it, so that we can be wise stewards of our future.

The President has proposed in the FY 1991 budget an aggressive, multi-agency research program to reduce the scientific uncertainties associated with global change. NASA is central to this activity. We are to apply our expertise in remote sensing to use the global perspective that is available from space to understand how the Earth works as an integrated system. We call our program Mission to Planet Earth. It consists of (i) some nineteen near-term flight missions, including the new Earth Probes program, that will expand our knowledge of aspects of global change; (ii) an integrated and open data system that will be available by 1994 to draw maximum information from existing and upcoming missions; (iii) an expanded scientific research program; and, (iv) a new start in the FY 1991 budget for the Earth Observing System, which will provide comprehensive, long-term observations of the whole Earth and its component parts, sufficient to serve as the basis for predictive models of the future of the planet.

Mission to Planet Earth is unlike any other NASA Space Science Program. It is not intended to increase incrementally our knowledge of the Earth. Rather, it is intended to increase with all due haste our knowledge of all aspects of the Earth system to where we have sufficient understanding to make sound policy decisions. This will require aggressive and sustained funding.

However, consider the alternative. It is clear that global changes can have significant economic and sociological impact on our nation. Indeed, the economic impact of a decision to drastically reduce fossil fuel consumption could be measured in hundreds of billion dollars per year. Thus, we must make the investment today that will reduce the scientific uncertainties associated with global change issues, so that our actions can protect both the future of our environment without unduly jeopardizing our economy and way of life.

There is a bright side, as well, to the prospects of the future of the species. The time may come when we will work on other planets, extending our presence throughout the solar system. And

we have the good fortune of being the generation that will begin the journey.

The President has called upon us through the Space Exploration Initiative to return to the moon, and then proceed to Mars. Science is an integral part of this activity, and in the FY 1991 budget we provide support (i) for life science research which is essential to any human activity in space, (ii) to continue the robotic exploration of the moon and Mars, and (iii) to undertake planning for the unique opportunities for science that the moon offers.

The FY 1991 budget request for NASA is of historical significance. It provides for a renaissance in space science; we will marvel at the discoveries that will unfold before us in the coming years. But more important, it is a budget request that future generations will look back upon and be grateful for our wisdom. It begins the lengthy process of developing a sufficient understanding of the Earth so that ours and future generations can know the consequences of their actions. It begins the inevitable journey of this civilization into the solar system.

Permit me now to describe in more detail some of our recent accomplishments and our plans for FY 1990.

1989 PROGRESS AND ACCOMPLISHMENTS

In May, the Space Shuttle deployed the Magellan spacecraft, which will arrive this August at Venus, where it will spend several years mapping the planet's surface. In August, 4.4 billion miles and 12 years after launch, the Voyager 2 spacecraft arrived at its final destination on its "Grand Tour" of the outer planets -- Neptune, and literally excited the world with its discoveries. In October, Galileo began its circuitous journey to Jupiter, where it will drop a probe into the Jovian atmosphere and perform an extended tour of its satellites. Finally, in November, we launched the Cosmic Background Explorer (COBE) to measure the radiation remaining from the "Big Bang." Exciting early data from this mission has already challenged our present understanding of the early universe.

1990 PLANS AND OBJECTIVES

NASA's launch manifest calls for eight major Space Science launches in 1990; six on the Shuttle and two aboard expendable launch vehicles. In addition to the ambitious number of space science launches planned this year, many of our operational spacecraft will achieve significant scientific milestones in the coming months. Voyager 1 has completed its look back at the

planets, and the 64 images it collected will be pieced into a photo mosaic of our solar system which will be available later this summer. Galileo completed its Venus flyby in February, testing its scientific instruments and acquiring the momentum necessary to carry it by the Earth in December, and eventually on its way for a 1995 rendezvous with Jupiter. COBE completes its first sky survey in June. Magellan arrives at Venus on August 10, and begins mapping operations.

OSSA STRATEGIC PLAN

To attain and continue this unparalleled level of activity, we have diligently practiced strategic planning for our Space Science and Applications (OSSA) program. Now in its third year, the OSSA strategic plan continues to act as a guide with which to manage our ongoing programs and to plan for the future. The strategic plan continues to balance the need for major, moderate, and small missions. The plan charts our course as major users of Space Station Freedom. It affirms the importance of a strong research base. Perhaps, most importantly, the plan provides a clear process for making near-term decisions to allocate resources and plan for the future.

The strategic plan expands this year to be responsive to two major Presidential initiatives, while preserving the integrity of OSSA's core programs.

The fiscal year 1991 budget follows the five basic themes outlined in the OSSA core strategic plan, and also provides strong support for the U. S. Global Change Research Program and the Space Exploration Initiative.

ON-GOING PROGRAM

First, we have provided for the completion of our on-going programs. On April 25, the Shuttle deployed the Hubble Space Telescope, a cooperative program with the European Space Agency. The first of the four Great Observatories, Hubble will probe the universe with exceptional precision and clarity, allowing us to see farther than ever before, revolutionizing the study of astronomy. Next week, we resume our series of scientific research laboratory flights on the Shuttle with the launch of the Spacelab mission, Astro-1, carrying four telescopes which will detect ultra-violet and X-ray radiation from some of the most chaotic and fascinating objects in the universe. Astro-1 will also feature the shuttle astronauts conducting a live "space classroom" lesson on the astronomical features being observed by the telescopes. Also in May, the joint U.S. and Federal Republic of Germany Roentgen Satellite (ROSAT) will launch aboard a Delta

II rocket to study X-rays from cosmic sources. In June, the Combined Release and Radiation Effects Satellite (CRRES) will be sent aloft on its Atlas Centaur rocket to map the Earth's radiation belts during the peak solar activity cycle known as solar maximum. In August, the nine-day SLS-1 mission will fly as the first in an ongoing series of dedicated Life Sciences Spacelab missions. In October, it's back to the planets again with the Shuttle launch of the joint NASA/European Space Agency Ulysses mission, first to Jupiter and then over the poles of the Sun. November ushers out the second of the four Great Observatories, when we deploy the Gamma Ray Observatory from the Shuttle to investigate the forces of neutron stars and black holes. Finally, we will close out the calendar year with the third Spacelab mission of 1990, the International Microgravity Laboratory, focusing on both materials and life sciences research.

Our ongoing program also continues the development of important projects like the Upper Atmosphere Research Satellite (UARS), scheduled for launch in 1991; the joint NASA/French Space Agency Ocean Topography Experiment (TOPEX/POSEIDON) and the Mars Observer, both scheduled for launch in 1992; the Advanced X-Ray Astrophysics Facility (AXAF), with a 1997 launch date; and the Comet Rendezvous Asteroid Flyby (CRAF) and Cassini missions with our partners, Germany and the European Space Agency, planned for launch in 1995 and 1996 respectively.

LEADERSHIP INITIATIVE

The strategic plan also provides for programs designed to maintain U.S. leadership in space science and applications. The Earth Observing System (EOS), the centerpiece of the Mission to Planet Earth and an essential component of the President's U. S. Global Change Research Program, will provide U.S. leadership in the search to understand our environment.

It is important to realize that EOS is a research program which is designed to yield the maximum information about the Earth, and any impacts due to human activities, in the shortest possible time. It provides for a data and information system that will enhance the return for existing missions and missions that will fly in the next few years. It provides for an immediate and substantial growth in support for scientific research. EOS provides the comprehensive long-term observations necessary to understand how the Earth responds to human interactions. Indeed, the bulk of the funding for EOS will support the acquisition and analysis of data, and its scientific interpretation. Only 40% of the total program funding is for space hardware.

During the next several years, our knowledge of the Earth will increase substantially. NASA will conduct 19 Earth science missions, which will study various aspects of how the Earth works. The Upper Atmospheric Research Satellite will make definitive measurements of the chemistry and dynamics of the upper atmosphere, and thus of ozone depletion. TOPEX/POSEIDON will reveal more about the circulation of the world's oceans than all the ships in history. The NASA Scatterometer will study wind stress on the oceans. The ATLAS Spacelab missions will study the atmosphere, and the Shuttle Radar Lab, the topology of the land. There will be numerous Earth Probes: small missions in Earth science to pursue focused problems. Also, our international partners, the Japanese, Europeans and Canadians, will launch seven missions, some of which will carry U.S. experiments, and many of which we will help track in return for access to their data. And NOAA will continue to operate meteorological satellites.

To make optimum use of the data from these upcoming missions, we need to improve the computational capabilities in Earth science, and the access of researchers to this data through networks and archiving facilities. Included in the funding for EOS is substantial support to develop the EOS Data and Information System (EOSDIS), essential elements of which will be brought online in the early 1990's, well in advance of the launch of the EOS platforms. EOSDIS will allow scientists to derive maximum information from existing and upcoming missions, and, in turn, to use this mission data to test and perfect EOSDIS in advance of the larger data flows from the EOS platforms. Moreover, the open architecture of EOSDIS will herald a new era of data management and exchange, among U.S. researchers and with those from other nations.

Data alone, of course, does not yield understanding. That will require scientists interpreting the data, developing concepts for the processes which control the Earth, and building predictive models of its future. EOS includes funding to effectively double the research community that will dedicate itself to understanding global change, and the program will support graduate fellowships to insure continuity of this research base into the future. The funding for scientific research is built in from the inception of the EOS program.

We need to recognize, however, that the Earth may be the most complicated planet in the solar system, with its interactions among the atmosphere, the oceans, and the biota, and that we are

remarkably ignorant of how it works. Consider, for example, aspects of greenhouse warming. Carbon dioxide from industrial activities is growing in the atmosphere and has the potential of increasing the temperature through greenhouse warming. However, the amount of carbon dioxide in the atmosphere depends on the amount absorbed by the Earth's biota. The response of the atmosphere to increased greenhouse warming may depend on whether there is a change in the cloud cover of the Earth, and at what altitude the clouds form. The response of the climate, in particular regional effects, will depend on changes in the global circulation of heat through the oceans. Indeed, the response of the Earth to human interactions will depend on the coupling and interactions which occur among the various components of the Earth. These couplings provide feedback mechanisms that could either enhance or mitigate the effects of global change. The essential challenge to us, then, is to understand which feedback mechanisms are dominant, and how the Earth will respond.

The Earth science missions that will fly in the next few years will advance our understanding of the Earth and its systems. They will, in essence, tell us where we <u>are</u>. They will not tell us what to expect in the future for our Earth. They will not yield definitive answers to how the coupling and feedback systems of the Earth work, and thus to how the Earth will respond to global change. In some cases the instruments that will fly have inadequate resolution and sensitivity. More important, they will not provide comprehensive observations of the components of the Earth at the same time. To understand how the oceans, atmosphere and biosphere interact and are coupled, it is necessary to observe the changes in these components, and the resulting responses in other components, at the same time.

The EOS platforms are designed to provide the necessary observations to understand the Earth as an integrated system. The first platform, which will launch in FY 1998, is devoted to measurements of the surface of the Earth, and to the conditions of the lower atmosphere. The second platform, which will fly two and a half years later, is devoted to measurements of the chemistry of the upper atmosphere, the circulations of the oceans, and the behavior of the solid Earth. In addition, our international partners, the European Space Agency (ESA) and Japan are planning to build platforms which include accommodations for U.S. scientific instruments. All platforms are placed in polar Sun-synchronous orbit, to offer complete coverage of the Earth. Simultaneity is the key to successful observations by the EOS platforms. The size of the platforms has been dictated by the science results required to measurably advance our understanding

and predictive abilities. We have sought the constant involvement and advice from the Earth science community on the design of EOS, the choice of instruments, and the approach toward scientific research and data processing. In particular, the science community has consistently noted that a long-term, comprehensive set of simultaneous observations is the key to the success of the EOS program. Our fundamental concerns are assuring that the instruments are available in a timely fashion and ensuring that our program meets the scientific priorities and requirements laid out by the U.S. Global Change Research Program.

In line with these requirements the platforms are sized to accommodate those instruments which need to observe the Earth simultaneously, through the same column of air. All instruments that observe the surface of the Earth require substantial atmospheric corrections; knowledge of aerosol content, temperature, water vapor, etc. Thus, it is important to fly all the surface imagers and the instruments which determine atmospheric conditions on the same platform. This requires a total of eleven instruments, approximately 3000 kg of payload, to be flown together. This number of instruments is approximately equal to the number accommodated on the Upper Atmosphere Research Satellite (UARS); however, given the complexity of the EOS instruments, the total payload weight is 30% greater than that of UARS.

We need to track the global environment for some years to ensure that we understand the changes, and the processes responsible for them. EOS is designed to yield fifteen years of continuous data. Since the EOS platforms are in polar orbit, where there is no servicing from the Shuttle, and a reasonable design life for a spacecraft is five years, each EOS platform and instrument will be replaced on orbit twice by an identical platform, at five year intervals.

Processing the flow of EOS observations is critical to mission success. EOSDIS will handle about 10 terabytes of data every day -- about the equivalent of ten warehouses of magnetic tapes. And it will do so quickly -- we plan to process some data within 48 hours of receipt, to allow scientists to get their hands on it as soon as possible. To do this, EOSDIS will use a network of active archive sites and processing centers, and software to allow researchers to browse the files and order only what they want.

The EOS program will be managed by the Goddard Space Flight Center (GSFC). The FY 1991 budget includes funding to augment

the workforce at GSFC in direct support of the EOS program and begins funding necessary to undertake construction of an EOSDIS facility. Both of these elements are integral to the total EOS program.

The cost of EOS through the year 2000, including the instruments, the platforms, the data system, and the support for science, is approximately $17 billion, in real year dollars (inflation included). This cost is, of course, large compared to the cost of any previous space science project. However, the cost is very small compared to the value of the information EOS will provide to help chart the course this nation and the world should follow to insure both a healthy environment and a healthy economy.

SMALL MISSIONS

Third, the OSSA strategic plan provides for new flight opportunities in the near term for small missions. This year's small missions initiative responds to the critical and immediate need to address specific and highly focused problems in the Earth sciences. Earth Probes occupy a special niche as critical elements of the Mission to Planet Earth initiative, and are highly symbiotic in their relationship to both EOS and other NASA Earth sciences satellites. A series of Total Ozone Mapping Spectrometer (TOMS) instruments, with potential flights in 1991, 1993 and 1995, will measure atmospheric ozone concentrations and contribute to our current ozone models. The NASA Scatterometer, to be launched in 1995 aboard the Japanese ADEOS spacecraft, will study wind stress on the oceans and provide data needed in understanding the role of oceans in controlling climate. A number of other Earth Probes missions are proposed, e.g. the Tropical Rainfall Measuring Mission (TRMM) and an Ocean Productivity Experiment (formerly SeaWIFS).

SPACE STATION

Fourth, the strategic plan enables us to move aggressively, but sensibly, to build science instruments for the Space Station. This year, we will complete definition studies on our Space Biology Initiative (SBI) and begin the full development phase. The Space Biology Initiative provides for space hardware to conduct scientific research on Space Station Freedom. The facilities we are developing will be dedicated to space physiology, gravitational biology, exobiology, and closed ecological life support system (CELSS) testing and research.

We are also initiating the Biomedical Monitoring and Countermeasures (BMAC) program, an essential prerequisite to routine Space Station Freedom crew operations and a critical

requirement for the implementation of human exploration activities in space. BMAC will enable us to determine ways to maintain optimum crew health and performance to medically certify repeated extended-duration tours of duty for space station astronauts.

The information and experience we gain through both the Space Biology Initiative and the Biomedical and Monitoring Countermeasures program will enable us not only to maximize our utilization of the Space Station, but will also help us to understand and meet human needs associated with future manned exploration missions.

RESEARCH BASE

Fifth, the strategic plan ensures a vital and productive research base. Our 1991 budget provides for the on-going support of thousands of researchers and students to acquire and analyze data from previous missions. This year we will also expand the research base with the initiation of 3 Life Sciences Specialized Centers of Research and Training, and the introduction of the multi-disciplinary Origin of Solar Systems Program.

SPACE EXPLORATION INITIATIVE

In support of the President's major exploration initiative in the 1991 budget, OSSA has developed a separate Space Exploration Initiative (SEI) strategy which supplements our existing base program strategy and clearly focuses our attention on this important national undertaking.

The Office of Space Science and Applications has an important scientific role to play as NASA expands its efforts to send humans back to the Moon and "on a journey into tomorrow" with a piloted mission to Mars. OSSA's support for SEI in FY 1991 can be characterized as a combination of: 1) on-going program activities, such as the Mars Observer to be launched in 1992 and elements of our Life Sciences program; 2) enhancements to the core program, including Mars Observer ground systems and software enhancements; and, 3) new initiatives, specifically the Lunar Observer and a series of satellites, known as Lifesat, to study the biological effects of space radiation.

SEI enhancements and initiatives to the OSSA program build logically upon our current programs and capabilities, as we work to address the requirements already identified through the agency's recent 90-day Exploration study, as well as requirements to be developed in the future. Our OSSA Space Exploration

Initiative strategy focuses on three major programmatic themes: meeting human needs; robotic exploration; and, in-situ science.

MEETING HUMAN NEEDS

Both the Space Biology Initiative and the Biomedical Monitoring and Countermeasure program, supporting Space Station utilization, will make significant contributions to our goal of understanding how to make it possible for humans to undertake long-term missions to the Moon and eventually Mars.

In addition to these important programs supporting OSSA's baseline strategy, we are also planning for a series of reusable satellites called Lifesat, designed to study the effects of space radiation on biological systems. Our full understanding of these effects is an important prerequisite for long-term human spaceflight. Lifesat will help us to: 1) determine radiation constraints for long duration human presence in space; 2) measure the biological response to the space radiation spectrum; 3) determine the synergy between radiation and microgravity effects; 4) test important pharmaceutical and gravity countermeasures; and 5) facilitate the establishment of acceptable risk levels. This year, we will complete satellite and payload definition studies, in order to begin development in 1992.

ROBOTIC EXPLORATION

NASA's strategy for exploration of the Moon and Mars will include both robotic and human missions. OSSA's robotic exploration efforts will: 1) provide for the enhancement of the Mars Observer ground data and software systems; 2) add the Mars Balloon Relay Experiment to the Mars Observer science payload to support selection of future landing sites; and, 3) preserve the 1996 launch opportunity for the Lunar Observer, with plans to begin the procurement of long lead-time parts in 1991 and full development in 1992.

As an element of the core strategic plan, OSSA has had under study a number of future space science missions, including the Lunar Observer, a one to two year mapping mission of the Moon in lunar polar orbit to provide a global scientific data base of the Moon. Within OSSA's new Space Exploration Initiative Strategy, Lunar Observer is identified as our highest priority SEI robotic mission. In order to provide timely support for future human activities on the Moon, and preserve our ability to launch as early as 1996, development for the Lunar Observer should begin in FY 1992. The Lunar Observer mission will measure globally the chemical and mineral composition of the Moon's surface, determine

surface topography and landform, measure the Moon's magnetic and gravitational fields -- providing first rate science data and facilitating the selection of future landing sites for human missions.

IN-SITU SCIENCE

With the Space Exploration Initiative, there are new opportunities for conducting exciting science on and from the Moon and Mars. This year, we will work with the Office of Aeronautics, Exploration and Technology to begin developing strategies and identifying advanced technology development priorities to take full advantage of these opportunities. We plan to solicit recommendations from our Exploration Science Working Group, the discipline subcommittees of the Space Science and Applications Advisory Committee, and the Space Studies Board to assure that all promising candidates for in-situ science are given full and careful consideration.

PROGRAM CONCERNS

I would like to emphasize one other critical element of the Space Science and Applications program, namely the NASA institution -- its people, facilities, and resources. The American people expect, and our laws require, NASA to deliver a first class civil space program. To fulfill our obligation to its citizens, our country must recognize that this requires adequate funding to 1) hire and retain scientists, engineers, and managers to lead our world class science and applications programs; 2) develop and build world class R & D facilities; and, 3) provide resources to adequately manage world class programs from coast to coast and around the world.

As stewards for this Nation's future in Space Science and Applications, we take these institutional commitments seriously. We are working to optimize today's resources as we seek to assure an adequate pool of scientists, engineers, and forward thinking individuals capable of leading us across the space frontier, and into the future.

We are making real investments today in our future workforce, through innovative educational partnerships like the Graduate Student Research Program and the Joint Venture in Education (JOVE) program. For example, JOVE pairs university faculty and their students with working NASA scientists and engineers. NASA provides hands-on exposure to its personnel, facilities, and scientific mission data; in exchange for a commitment from the participating university to conduct research and analysis, and initiate outreach programs in their community.

SUMMARY

Mr. Chairman, the budget request that I have presented to you elicits three emotions:

The first is a sense of excitement for what this budget will accomplish. Between the flight of Magellan last May and the completion of FY 1991, we will launch more space science missions than in the entire decade of the 1980's. We will be awash in new data and new discoveries, and the world will marvel at our accomplishments. There will be no doubt that the space science program of the United States is the best in the world.

The second is a sense of responsibility. We know that we are affecting our global environment, but the changes we will bequeath to our children and our grandchildren are unknown. However, with Mission to Planet Earth and the entire global change research program of the federal government we will not let this ignorance persist. We will reduce the uncertainties in the global changes that will result from human interactions, so that we and future generations can take responsible actions to protect the future of the planet.

And finally, there is a sense of hope. The space program has a clear direction again. We are returning to the Moon, and then on to Mars, and there are efforts we must begin in FY 1991 to make that possible. Let the great adventure begin again, and never stop as we extend the human presence throughout the solar system.

Thank you very much.

NASA
National Aeronautics and Space Administration

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April 3, 1990

Subcommittee on Science, Space and Technology

Committee on Commerce, Science and Transportation

United States Senate

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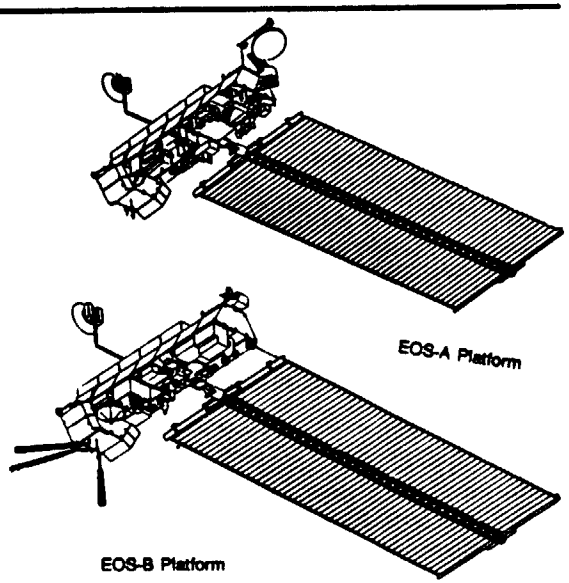

EARTH OBSERVING SYSTEM

101st Congress

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Mr. Chairman and Members of the Subcommittee:

I am very pleased to have the opportunity to appear before the subcommittee to discuss NASA's plans for a Mission to Planet Earth.

Mr. Chairman, we are at a unique point in human history. We know we are affecting the Earth's global environment, yet the outcome of these effects on the world are unknown. Some of these activities are dramatic. We burn the world's forests at the equivalent rate of one state of Tennessee per year. We load the Earth's atmosphere with carbon in the form of carbon dioxide, a known greenhouse gas, at the rate of five billion metric tons per year.

The planet we are affecting is also the most complicated in the solar system. It is the only one with oceans and life; and the interactions among the oceans and life, as well as the atmosphere, the land surface, and the ice, produce a very complicated set of mechanisms which control how the Earth behaves. And we are remarkably ignorant of how it all works.

In essence, then, we are conducting a gigantic global experiment, the outcome of which is unknown. And since nature tends not always to work in our favor, we should be concerned that the outcome will not be favorable. Clearly, we cannot let this ignorance persist - we need to understand the Earth in a global

sense, and we need to do so immediately. We need to understand how it works so that we can better assess how to effectively protect the future of the planet.

We need to recognize that because of these large uncertainties, it is difficult to know what actions should be taken. This is particularly true considering the significant economic and societal input associated with some suggested actions. A reduction in fossil fuel consumption, for example, by as little as 20% would have a dramatic impact on the world's economy. Clearly, we need an accurate scientific road map for how the Earth might respond to human activities so that we can chart a course which both protects our environment and our economy.

The President has proposed a comprehensive global change research program, the U.S. Global Change Research Program, to reduce the scientific uncertainties of pending global change. NASA's part of this program is to conduct the **Mission to Planet Earth**. This is not a traditional science program. This is not a program in which we are trying to incrementally increase our knowledge of the Earth. This is a crash program designed to rapidly expand our knowledge of the Earth so that we can provide the scientific basis for sound policy decisions.

As part of this program, NASA will launch some 19 Earth science missions over the next few years which will increase our knowledge of the Earth. We will construct a major data system that will come on line in the 1994 time frame to be able to incorporate the data from these upcoming missions (and from past missions) so that we learn as much as we can about the Earth and how it works. And we will double our support for basic research in Earth science.

But to understand sufficiently how the Earth works so that we can predict its future, we must develop an understanding of how the Earth works as a coupled system. Consider, for example, aspects of greenhouse warming. Carbon dioxide from industrial pollution is growing in the atmosphere and has the potential of increasing the temperature through greenhouse warming. However, the amount of carbon dioxide in the atmosphere depends on the amount absorbed by the Earth's biota. The response of the atmosphere to increased greenhouse warming may depend on whether there is a change in the cloud cover of the Earth, and at what altitude the clouds form. The response of the climate, in particular regional effects, will depend on changes in the global circulation of heat through the oceans. Indeed, the response of the Earth to human interactions will depend on the coupling and interactions which

occur among the various components of the Earth. These couplings generate feedback mechanisms that could either enhance or mitigate the effects of global change. The essential challenge to us, then, is to understand which feedback mechanisms are dominant, and how the Earth will respond.

The Earth science missions that will fly in the next few years will not yield definitive answers to how these coupling and feedback systems of the Earth work, and thus to how the Earth will respond to global change. In some cases the instruments that will fly have inadequate resolution and sensitivity. More important, they will not provide comprehensive observations of the components of the Earth at the same time. It is a simple reality that to understand how the oceans and the atmosphere and the biota interact and are coupled, it is necessary to observe the changes in these components, and the resulting responses in other components, at the same time.

To provide comprehensive observations of the Earth as a system, NASA will fly the **Earth Observing System**, or **EOS**. Two well-instrumented platforms in polar orbit, together with platforms from Europe and Japan, will provide comprehensive, long-term observations of the interactions among the components of the Earth, so that we can understand how the Earth works and project how it will respond to our continuing influence.

The cost of Mission to Planet Earth is considerable -- it is comparable to all the other science programs in NASA combined. Yet compared to the value of the information, the cost is minuscule. Mission to Planet Earth contributes to the scientific basis designed to support policy decisions focused on protecting both the global environment and the world economy.

I would like now to elaborate on several aspects of Mission to Planet Earth.

1. What are the components of Mission to Planet Earth?
2. What is the Earth Observing System (EOS)?
3. Why must some instruments fly together?
4. How will NASA process the data from EOS?
5. What is NASA doing to get ready for EOS?
6. What role does education play in EOS?
7. How much will EOS cost?

What are the components of Mission to Planet Earth?

The President has proposed in the FY 1991 budget an aggressive, multi-agency research program to reduce the scientific uncertainties associated with global change. This program was developed by the Committee on Earth Science, a Federal interagency committee formed under the President's Science Advisor. With unprecedented cooperation, agreement, and a clear consensus, representatives of thirteen Federal agencies formulated the strategy for the U.S. Global Change Research Program. The priorities of this program are to document change in the Earth system using observational programs and data management systems, to carry out focused studies on controlling processes to improve our understanding, and to develop integrated conceptual and predictive models.

NASA's programs are central to the mission of the U.S. Global Change Research Program. Our major role is to apply our expertise in remote sensing to use the global perspective that is available only from space to understand how the Earth works as an integrated system. We call our program Mission to Planet Earth. It consists of (i) some nineteen near-term flight missions that will expand our knowledge of aspects of global change; (ii) an integrated data system that will be available by 1994 to draw maximum information from existing and upcoming missions; (iii) an expanded scientific research program; (iv) a series of small, focused missions known as Earth Probes; and (v) the Earth Observing System (EOS), which will provide comprehensive, long-term observations of the whole Earth and its component parts, sufficient to serve as the basis for predictive models of the future of the planet.

Mission to Planet Earth is unlike any other NASA Space Science Program. It is intended to broaden, with all due haste, our understanding of all aspects of the Earth system -- to broaden our understanding to a point where we will have sufficient knowledge of the intricate elements of the Earth system to make sound policy decisions. This program will require substantial and sustained funding levels, and will dwarf any other Space Science activity.

What is the Earth Observing System (EOS)?

The Earth Observing System (EOS), the centerpiece of the Mission to Planet Earth and an essential component of the President's U.S. Global Change Research Program, will provide U.S. leadership in the search to understand our environment. The science program for EOS reflects an integrated observational approach to many of the difficult science questions which face us while providing a direct response to the science priorities defined by the U.S. Global Change Research Program.

It is important to realize that EOS is a research program, which is designed to yield the maximum information about the Earth, and any impacts due to human activities, in the shortest possible time. It provides for a data and information system that will enhance the return for past and current missions, and missions that will fly in the next few years. It provides for an immediate and substantial growth in support for scientific research. It provides the comprehensive long-term global observations necessary to understand how the Earth responds to human interactions. In fact, a major potion of the funding for EOS will support the acquisition and analysis of data, and its scientific interpretation.

Only 40% of the funding is for space hardware. This is unprecedented in terms of funding distribution for space science programs. In planning this program, we recognized early on that the need to acquire data in an expeditious manner -- a manner which would support policy makers in their decision process -- warranted an aggressive program relative to data acquisition and analysis.

In order to meet the measurement goals of EOS science, the EOS program consists of two series of polar orbiting platforms with complementary payloads launched on Titan IV expendable launch vehicles. Each platform will be replaced every 5 years to achieve the 15 year mission lifetime goal.

The EOS platforms are designed to provide the comprehensive global observations to understand the Earth as an integrated system. The first platform, which will launch in FY 1998, is devoted to measurements of the surface of the Earth, and to the conditions of the lower atmosphere. The second platform, which will fly two and a half years later, is devoted to measurements of the chemistry of the upper atmosphere, the circulation of the oceans, and the behavior of the solid Earth. In addition, our

international partners, the European Space Agency (ESA) and Japan, are planning to build platforms which include accommodations for U.S. scientific instruments.

The requirement for global coverage from EOS dictates that these instruments be flown in a near-polar orbit. To avoid biasing EOS observations with the combined effects of diurnal and seasonal effects, sun-synchronous orbits have been selected for EOS. The 705-km, 98.2 degree inclination orbit planned for EOS will provide a quasi-two-day repeat pattern for frequent global coverage, while being in an altitude range acceptable to both wide-swath-width and high-resolution instruments.

The equator crossing time for EOS has been selected as 1:30 pm ascending node. This choice ensures strong solar illumination to improve the signal-to-noise performance of instruments measuring reflected sunlight. It is also designed to provide observations of terrestrial vegetation under conditions of near-maximum thermal and water stress. This choice of orbit also means that those EOS instruments with operational potential will be flown under conditions that are close to those of the primary NOAA polar operational mission.

The proposed payload groupings are the result of extensive analysis of accommodations, science requirements, international partner plans, cost, schedule, and other factors. The final allocation of instruments and other payload elements to specific platforms will be in accordance with selection confirmation decisions to be made in September 1990 for EOS-A and approximately one year later for EOS-B.

Why Must Some Instruments Fly Together?

Within the overall payload of EOS, there are sets of instruments which can complement each other in the production of desired observations. In some instances, certain instrument suites are required to yield corrective data. To do this, they must make their measurements simultaneously. These sets dictate certain minimum payload groupings around which alternative scenarios have been built and assessed. The time scales for significant variations in the phenomena being observed define the meaning of simultaneous. For EOS, there are four levels of simultaneity, which are detailed in the following paragraphs.

First, all EOS instruments need to be in orbit at the same time. This enables many of the variable components of the Earth system to be characterized globally every 1 to 3 days. This requirement is the reason behind the extensive set of planned observing capabilities. While many aspects of the Earth do not change on the time scale of days, all of the EOS instruments observe dynamic phenomena that do change rapidly.

Second, the atmosphere changes on time scales as short as 10 seconds. Changes in aerosol concentrations, temperature, water vapor distributions, and clouds can significantly affect the atmospheric contribution to signals received by optical instruments. This imposes simultaneity requirements on three separate sets of instruments to make their observations within a minute of one another and from the same perspective.

- The first group of these instruments includes those that measure the troposphere. If observations are made at the same time, data from these instruments can be combined to produce improved algorithms for atmospheric temperature and moisture profiles, cloud properties, aerosol column densities, and instantaneous rain rates.

- The second grouping includes the optical surface imagers. Although each of these imagers operates at different spatial resolutions, they share specific spectral bands. Surface imaging optical instruments always employ atmospheric corrections. For example, if the Moderate-Resolution Imaging Spectrometer (MODIS) and the High-Resolution Imaging Spectrometer (HIRIS) view the surface through the same atmosphere (i.e., simultaneously and from the same perspective), their data will be directly intercomparable before atmospheric corrections are applied. This will remove a major source of potential ambiguity from the results of such intercomparisons. Furthermore, the atmospheric corrections of the optical surface imagers may be aided by data from the atmospheric sensors in the first group.

- The third group of instruments are those that measure the different components of stratospheric chemical composition. If these instruments view the same stratospheric air mass at the same time, chemical concentrations from one instrument can be reasonably combined with those from another for a more comprehensive set of observations to use in comparison with localized photochemical models.

Third, vegetation canopies respond to environmental conditions on many time scales, but typical responses to drying conditions and variations in insolation may take as little as an hour. Consequently, those instruments used to study terrestrial vegetation need to make their measurements of a given site within an hour. This set of instruments includes all surface imagers within the proposed EOS payload. If these instruments are on platforms in the same orbit, even if they are on more than one platform, they can have the opportunity to view the same sites within 1 hour of each other. If they are flown in different orbits, there would only be intermittent opportunities for simultaneous viewing within the time requirement.

Fourth, measurements produced by the EOS Altimeter (ALT) and the Geosciences Laser Ranging System (GLRS) instrument both require precise knowledge of spacecraft location. The Global Positioning Satellite (GPS) Geoscience Instrument (GGI) on EOS is intended to provide this information. Flying these three devices on the same spacecraft allows them to share spacecraft location information.

The platforms are sized to accommodate those instruments which need to observe the Earth simultaneously, through the same column of air. All instruments that observe the surface of the Earth require substantial atmospheric corrections; knowledge of aerosol content, temperature, water vapor, etc. Thus, it is important to fly all the surface imagers and the instruments which determine atmospheric conditions on the same platform. This requires a total of eleven instruments, approximately 3000 kg of payload, to be flown together. This number of instruments is approximately equal to the number accommodated on the Upper Atmosphere Research Satellite (UARS); however, given the complexity of the EOS instruments, the total payload weight is 30% greater than that of UARS. In addition, EOS has the capability to manage over 10,000 times more data than UARS.

We have sought the constant advice and review of the Earth science community on the design of EOS, the choice of instruments, and the approach toward scientific research and data processing. In particular, the science community has consistently noted that a long-term, comprehensive set of simultaneous observations are the key to the success of the EOS program. Our fundamental concerns are assuring that the instruments are available in a timely fashion, and ensuring that our program meets the scientific priorities and requirements laid out by the U.S. Global Change Research Program. The size of the platforms, and their timing for launch, are simply an outgrowth of these science requirements. The challenge of the EOS

platforms is directly related to the development, testing, and integration of the science instruments on those platforms, not the management of the platforms or the number of platforms which are built.

We will need to track the global environment for some years to ensure that we understand the changes, and the processes responsible for them. EOS is designed to yield fifteen years of continuous data. Since the EOS platforms are in polar orbit, where there is no servicing from the Shuttle, and a reasonable design life for a spacecraft is five years, each EOS platform will be replaced on orbit twice by an identical platform, at five year intervals.

How Will NASA Process the Data From EOS?

The EOS Program has put a major emphasis on the EOS Data and Information System (EOSDIS). EOSDIS is planned to acquire a comprehensive, global, 15-year data set, to maximize the utility of this data set for scientific purposes, and to facilitate its easy access by the research community. In addition to data processing, archival, and distribution facilities, the EOSDIS includes the necessary capabilities for the command and control of the spacecraft.

The development of EOSDIS will be initiated immediately by building on the existing infrastructure within the research community. It will implement an architecture which is open and distributed, so that it can evolve with advances in computing and networking technology. The near-term objectives are to support the research and analysis of data which both exist and will come from the near-term pre-EOS missions. In this way, the research community can gain valuable early experience in preparation for the future large EOS data volume.

Archived data sets, in addition to those from the EOS satellites, will include complementary <u>in situ</u> and satellite data. EOS will also involve the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, the National Science Foundation, and other agencies.

There will be two types of data products: standard and specialized. Standard products will be generated and archived at Active Archive Centers around the country (all of which are existing data archives); the target time for the availability of engineering-level products is within 48 hours of collection,

while the target for derived geophysical products is within 96 hours. Specialized products will be generated by individual investigators and made available to EOSDIS for archiving and distribution, as appropriate.

The EOSDIS data policy specifies that all data and derived products be available to all research users, with no preference given to EOS investigators. Research users in the U.S. and participating countries will pay only the nominal cost of data reproduction and delivery; they will be required to agree to publish their results and to make available supporting information, including methods for analyzing data. Research users in other countries may propose cooperative projects and associated "in kind" contributions (i.e., provide similar access to appropriate satellite, aircraft, and surface-based data) in exchange for access to EOS data on similar terms. Access to the raw data stream will be provided to operational agencies for forecasting purposes. NASA will provide for the commercial distribution of data on a non-discriminatory basis to all other users.

What is NASA Doing to get Ready for EOS?

During the next several years, our knowledge of the Earth will increase substantially. NASA will execute 19 Earth science missions, which will study various aspects of how the Earth works. The Upper Atmospheric Research Satellite (UARS) will make definitive measurements of the chemistry and dynamics of the upper atmosphere, and thus of ozone depletion. A series of Total Ozone Mapping Spectrometer (TOMS) instruments, with potential flights in 1991, 1993 and 1995, will measure atmospheric ozone concentrations and contribute to our current models. The joint U.S./French TOPEX/POSEIDON mission will reveal more about the circulation of the world's oceans than all the ships in history. The NASA Scatterometer, to be launched in 1995 aboard the Japanese ADEOS spacecraft, will study wind stress on the oceans. The ATLAS Spacelab missions will study the atmosphere, and Shuttle Radar Lab, the topology of the land. Numerous Earth Probes missions in addition to TOMS are proposed; small missions in Earth science to pursue focused problems, e.g. the Tropical Rainfall Measuring Mission and an Ocean Productivity Experiment. Also, our international partners, the Japanese, Europeans, and Canadians, will launch seven missions, some of which will carry U.S. experiments, and many of which we will help track in return for access to their data. In addition, NOAA will continue to operate meteorological satellites.

To make optimum use of the data from these upcoming missions, we need to improve the computational capabilities in Earth science, and the access of researchers to this data through networks and archiving facilities. Included in the funding for EOS is substantial support to develop the EOSDIS, essential elements of which will be brought online in the early 1990's, in advance of the launch of the EOS platforms. EOSDIS will be used to derive maximum information from existing and upcoming missions; in turn, the data from these missions will be used to test and perfect EOSDIS in advance of the larger data flows from the EOS platforms.

What Role Does Education Play in EOS?

Data alone, of course, does not yield understanding. That will require scientists interpreting the data, developing concepts for the processes which control the Earth, and building predictive models of its future. EOS also includes funding to effectively double the research community that will dedicate itself to understanding global change, and the program will support graduate fellowships to insure continuity of this research base into the future. The funding for scientific research has been included from the inception of the EOS program.

Education is the key to successfully addressing the habitability of our planet over the long term. The upcoming 19 Earth science missions mentioned earlier can be the conduit to educate the public, and particularly the young, about the importance of the Earth's processes. As with other space missions, EOS and other Earth science efforts will encourage young people to take up science and math with a concrete goal in mind -- working for the Earth.

For example, we have identified specific funding in the EOS budget to establish an Earth Science Fellowship Program. Starting with 25 fellowships to be awarded in 1990, the program will fund up to 150 graduate students per year for the duration of the mission. The EOS Fellowship program will increase the number of Earth scientists and engineers. A national competition is planned to recommend and make awards for research support to graduate students enrolled in full-time Ph.D. programs at accredited U.S. universities.

Awards will be made for an initial 1-year term and may be renewed annually up to 3 years, based on satisfactory progress as reflected in academic performance and evaluations by the faculty advisor. Applications will be considered for research on global biogeochemical cycles, radiation and physical climate interactions, the hydrological cycle, and solid Earth processes. Atmospheric and ocean physics, chemistry and biology, ecosystem dynamics, soil science, geology, geophysics, and cryospheric processes are all acceptable areas of research, providing that the specific research topic is relevant to NASA's global change research efforts (the Earth Observing System and Mission to Planet Earth).

How Much Will EOS Cost?

EOS will be the largest space science mission ever undertaken. Through the year 2000, the cost of EOS, including the instruments, the platforms, the data system, and the support for science, is approximately $17 billion in real year dollars (inflation included). The cost of all the EOS platforms and instruments, for example, is equal to what has and will be spent on the four Great Observatories for astronomy.

However, the key difference between EOS and other space science missions is how the money will be spent. In the EOS program, 60% of total funds will support ground operations, data and most importantly science. On most major missions, the majority of the funds goes for space hardware with only 30% allotted for science and data. The EOS cost ratio is driven by the volume of data, i.e., nearly 50,000 terabytes, and our determination that EOS produce reliable predictions of the future as soon as possible.

The EOS program will be managed by the Goddard Space Flight Center (GSFC). The FY 1991 budget includes funding to augment the workforce at GSFC in direct support of the EOS program and begins funding necessary to undertake construction of an EOSDIS facility. Both of these elements are integral to the total EOS program and required for its timely initiation.

However large the cost of EOS is in comparison with previous space science projects, its cost is truly minuscule compared to the cost of taking the wrong action on global change. For example, estimates for the cost to substantially reduce fossil fuel consumption can exceed a trillion dollars per year to the world's economy. EOS will give us the information to chart a course that both protects the environment and the economy.

SUMMARY

Mr. Chairman, we have a responsibility. We know that we are affecting our global environment, yet the outcome of these effects on the world that we will bequeath to our children and our grandchildren is unknown. We cannot let this ignorance persist. We need to undertake the Mission to Planet Earth and the entire global change research program of the federal government so that we can reduce the uncertainties in the pending global changes, and be, as a result, wise stewards of the future of the planet.

Thank you, very much.

Hold for Release Until
March 13, 1990

Statement of

James T. Rose
Assistant Administrator
Office of Commercial Programs
National Aeronautics and Space Administration

before the

Subcommittee on Space Science and Applications
Committee on Science, Space and Technology
House of Representatives

Mr. Chairman and Distinguished Members of the Subcommittee:

There is increasing recognition, both in the U.S. and abroad, that space has attributes that are of great value. These resources and characteristics will play a major role in opening a new economic frontier for the spacefaring nations of the world.

It is clear that commercial development is both a logical progression in America's civil space efforts and a prudent competitive strategy. NASA's Office of Commercial Programs (OCP) is the focal point for the agency's efforts to stimulate and assist expanded involvement and investment by the U.S. private sector in civil space activities. OCP also helps bring about the commercial application of space technology.

The past year was exciting for OCP's commercial development program. We witnessed the first federally licensed commercial launch, the first corporation formed as a direct result of work done in cooperation with a NASA Center for the Commercial Development of Space (CCDS), and the first technology spinoff from a CCDS. I am pleased to have the opportunity to discuss these important programs. I will begin with a description of our efforts to encourage and support the commercial development of space.

COMMERCIAL DEVELOPMENT OF SPACE

True commercial space is achieved when industries are established that generate new products and services for private markets. Development of these new products and services will, in turn, support the growth of other commercial space industries, such as transportation and infrastructure.

Our challenge is to conduct a program that helps industries develop commercial space markets, and cost-effective commercial space transportation systems and infrastructure. We believe that we have been successful in structuring a comprehensive and aggressive program which meets this challenge. It is a bounded program, not just a level of effort. The activities of this program will lead to the creation of new products and services, leading to new markets and businesses. These, in turn, will drive the need for new cost-effective commercial space transportation and infrastructure.

1. Involving Industry in Planning for Office of Commercial Programs Activities. Since commercial development of space will ultimately be done by the private sector, we have sought and obtained significant industry advice and support in planning and developing our program.

a. Commercial Programs Advisory Committee (CPAC). One of NASA's goals is to help the private sector develop commercial space as a new sector of the national economy. CPAC was established in FY 1989 as a standing committee of the NASA Advisory Council. Unlike ad hoc committees, CPAC is able to provide NASA with continuing advice on the proper roles and responsibilities of government and industry in the commercial development of space. CPAC is composed of corporate Chief Executive Officers, university presidents, and is chaired by Mr. Edward Donley, Chairman of the Executive Committee, Air Products and Chemicals, Incorporated.

In 1989, CPAC published its report, "Charting the Course: U.S. Space Enterprise and Space Industrial Competitiveness," which summarizes the results of its first year of work. It proposes nine key recommendations that executive branch leaders, government agencies, and the Congress can implement

to foster U.S. space enterprise and space industrial development. NASA is currently reviewing these recommendations to determine appropriate action.

b. Strategic Planning. In FY 1988, NASA requested the American Institute of Aeronautics and Astronautics (AIAA) to conduct a study of issues and potential objectives associated with commercial development of space. AIAA formed a steering committee consisting of senior-level, private sector managers with considerable experience in the commercial space environment. The resulting study document, "Issues in Strategic Planning for Commercial Space Growth," represents inputs from more than 90 industry representatives, and is being used to support OCP strategic plan development.

c. Infrastructure Policy. Based on industry input, NASA has also refined the criteria and guidelines used for evaluating the infrastructure proposals coming from the private sector. Establishing appropriate criteria and developing appropriate processes are both necessary to increase NASA's planning capability and to heighten the potential for success of the proposed ventures.

2. Supporting the Development of New Industries. True commerce, the buying and selling of commodities, is characterized by the private sector developing new products and services for private sector markets. A sound technology base is the fundamental element upon which these markets, and ultimately, industries are built. These new markets, in turn, will build a demand for new cost-efficient space transportation and infrastructure. However, new markets will not emerge overnight. They must be carefully nurtured. Our program is targeted toward helping industry overcome obstacles to entering these new markets. Two elements of this program are the CCDS Program and partnerships with U.S. industry through cooperative agreements.

a. The CCDS Program. NASA's 16 CCDS's are competitively selected consortia of universities, industries, and government involved in early research and testing phases of potentially commercially viable technologies. The CCDS's play a vital role in developing a technology base upon which to build new commercial space industries. The CCDS Program helps move emerging

technologies from the laboratory to the market place with speed and efficiency by leveraging a broad industry base to develop product-oriented technologies and stimulating commercial cost-effective transportation and infrastructure ventures.

(1) Leveraging a Broad Industry Base to Develop Product-oriented Technologies. The 16 CCDS's involve the active participation of 52 universities and 175 companies. Industry has proven its commitment by investing heavily in this cooperative program. For example, the average ratio of industry matching funds (measured in cash and in-kind services) to government funding for the 16 CCDS's, is approximately 2.2 to 1. The ratio of just the first five CCDS's, established by NASA in 1985, has risen to 3.4 to 1.

Sixty-one new technologies have been defined by the CCDS's. Extensive ground tests have proven the need for flight testing of these technologies in the space environment. Each technology will require a specific number of flight tests to mature it to the point that a decision can be made regarding the viability of commercial applications.

The CCDS Program establishes a technology base for the 61 identified technologies by 1995. The process is an interactive one, with industry determining potential applications throughout the entire time. We believe that with the current efforts, the maturation of these technologies will occur between 1990 and 1995. We have identified 5 that will mature by the end of 1990, 10 by the end of 1991, 19 during 1992, 14 in 1993, 7 in 1994, and 6 in 1995.

Maturing these technologies through a flight test program requires access to space. OCP has conducted a "bottoms-up" analysis to determine transportation requirements. Through 1995, 277 flight tests are planned, 12 of which will be carried out in the Shuttle cargo bay and 90 in the middeck/Spacelab. Seventy will be accommodated using a commercial payload module, 23 are scheduled for flights aboard expendable launch vehicles (ELV), 34 on sounding rockets, and 48 will fly as "GetAway Specials (GAS)" in the Shuttle payload bay. A

significant portion of our budget request for FY 1991 is for obtaining space transportation. This will be discussed in more detail in Section 3., FY 1991 Commercial Use of Space Budget Request.

Since the inception of CCDS's, the following experiments have been completed toward technology development: 935 drop tube/drop tower experiments; 12 Lear/KC-135 flights; 15 payload flight tests aboard 2 sounding rockets; and 5 flight tests aboard the Space Shuttle. Through these experiments, industrial researchers obtained invaluable data which contributed to decisions as to whether or not further flight tests are warranted.

The Center for Macromolecular Crystallography, University of Alabama-Birmingham, and industrial researchers has had experiments performed aboard the Space Shuttle launches STS-29 and -32 that, coupled with its 1988 experiments aboard STS-26, could lead to commercial in-space production of tiny protein crystals. High quality crystals were obtained from the protein and enzyme samples flown, and new knowledge regarding the samples was obtained. Four of the samples grew crystals of exceptional size and quality. Protein crystals are tools for scientists who are working to develop powerful new drugs to combat cancer, high blood pressure, organ transplant rejection, rheumatoid arthritis, and many other diseases. Payloads from the Center for Advanced Materials at the Battelle Laboratories, the Center for Bioserve Space Technologies at the University of Colorado, and the Center for Cell Research at Pennsylvania State University are scheduled for flights later this year.

The technologies under development at CCDS's are recognized as "new" by the industrial space community. Eighteen technologies have been patented, while 41 more are awaiting confirmation. CCDS's have also generated close to 800 technical publications in refereed journals, with 91 more in work.

A significant milestone was reached this year with the first CCDS technology spinoff. A collaborative effort between the Center for Commercial Development of Space Power (Auburn University) and Maxwell Laboratories has resulted in a stronger, more efficient power supply applicable to laser work now being marketed by Maxwell. While conducting research into space power equipment,

potential commercial applications to existing terrestrial markets have been identified. There are other efforts in process at the Center for Mapping (Ohio State University) potentially to spin off other technologies.

BioCryst, a Birmingham, Alabama, pharmaceutical company, was incorporated January 1, 1989, as the first corporate spinoff resulting from CCDS involvement. Their work was done in cooperation with the Center for Macromolecular Crystallography, University of Alabama-Birmingham. BioCryst was formed to apply the tools of X-ray crystallography and computerized molecular modelling to the development of new pharmaceutical compounds. BioCryst has already applied for patents for its work on anticancer drugs. Other groups are currently working to spin off two more companies.

(2) Stimulating Commercial Cost-effective Transportation and Infrastructure Ventures. On March 29, 1989, the CCDS for Space Materials Development at Huntsville, Alabama, successfully launched six CCDS-developed payloads on a commercially provided launcher, Starfire, at a cost of approximately $1.4 million. The cost included both the launch vehicle, launch and recovery system, and payload integration. Eight members of U.S. industry (two of which were start-up space companies), two other CCDS's, and three other universities were involved in the project. The suborbital flight, named Consort 1, provided 7 minutes of microgravity. The entire effort to integrate the payloads and commercially procure the launch services, and launch and recover the payloads took only 9 months, compared to the traditional 18-24 months. It demonstrated that academia and industry can move quickly to develop commercial opportunities for space research in a highly efficient and successful manner, with minimum government involvement.

A second commercial launch, the Consort 2, experienced a second-stage guidance failure within seconds after lift-off on November 15, 1989. Safety personnel were forced to destroy the booster, but the payload module was parachuted to safety. The payload was recovered undamaged and is being prepared to fly again in May 1990.

The next series of flights will occur in the late fall of 1990 aboard the Joust-1 vehicle. The more powerful Joust-1 will provide from 12-16 minutes of microgravity depending upon the payload mass as opposed the 6-8 minutes provided by the Consort depending its payload mass.

CCDS's are also planning and initiating a variety of hardware development projects to provide CCDS researchers with cost effective means of conducting experiments in space. One such project, in its second year of development by the Space Vacuum Epitaxy Center at the University of Houston, is a "wake shield" facility for space vacuum epitaxy research.

The Wake Shield Facility will provide a high ultrapure vacuum by pushing aside stray atoms and molecules found in low Earth orbit. Researchers can use this high vacuum with near infinite pumping speeds to grow thin films with hundreds of layers that are each only a few atoms thick. Such multilayered thin films can be used in opto-electronics, microwave amplifiers, and various electronic applications.

Comparative studies indicate that the estimated costs and time period for developing the Wake Shield Facility through commercial practices will be significantly less than for NASA to contract to build the facility itself. More importantly, purchasing the facility from commercial sources will also help to stimulate the growth of a private sector capability to manufacture commercially oriented space flight hardware. The facility is currently scheduled to fly in early 1992.

(3) Creating a Planning Function for Future Industry Needs and Requirements. OCP has initiated an activity, led by the Battelle CCDS, to work with the private sector in the development of space industries, particularly in the areas of transportation and infrastructure. Through the existing CCDS's, we have gained the active participation of the private sector in building the technology base essential to the commercial development of space. But this technology base does not address the issue of what transportation and infrastructure elements will be important to support the

new space industries as they develop and mature. The industry development activity will address these specific issues.

The Battelle CCDS is taking the lead in this activity. Battelle will work, both with the other CCDS's and with private sector companies directly, in identifying critical elements that must be in place in order to support the growing needs of successful private sector ventures. The ongoing recommendations resulting from this effort will assist the private sector in meeting its infrastructure and transportation needs.

By using the established CCDS structure, we will be facilitating the planning by industry for its own needs. It is vital, as part of our program, that we not only receive the input of industry in planning for the near-term, but also for the mid- and far-term.

b. Cooperative Agreements

(1) Description of the Program. NASA has developed a significant number of innovative working agreements to minimize business risks and give private firms access to our facilities and other capabilities. These agreements are each designed to meet requirements of different commercial ventures. The Joint Endeavor Agreement (JEA) and other types of agreements between NASA and the private sector are the instruments through which we attempt to mitigate the private sector's extraordinary up-front technical and financial risks associated with these capital investment projects. For example, under a JEA, the private sector partner funds experiments and the government provides the transportation and other services. Another innovative agreement is the Space Systems Development Agreement (SSDA) which can have deferred payment financing arrangements. NASA also enters into agreements to provide assistance, services, and facilities in support of the development of a commercial ELV industry.

(2) FY 1989 Cooperative Agreements Accomplishments. In FY 1989, NASA expanded its partnerships with U.S. industry through the signing of cooperative agreements providing support for industrial space research,

commercial space transportation, and the private development of space infrastructure and services.

(a) Corabi International Telemetrics, Incorporated, signed a Memorandum of Understanding (MOU) supporting the commercial development of telemedicine services for the Space Station Freedom.

(b) Coca-Cola Company signed an MOU in support of the firm's investigation of fluid dynamics, gas-liquid separation, and metering technologies in space.

(c) University Corporation for Atmospheric Research, Boulder, Colorado, signed a Memorandum of Agreement establishing the terms and conditions for use of the Space Shuttle's external tanks for suborbital experiments. Up to five designated external tanks will be made available.

(d) Global Outpost, Incorporated, signed an agreement to outline the activities they would undertake to address technical, safety, and business issues associated with commercial use of the Space Shuttle's external tanks.

(e) NASA also entered into agreements supporting the development of the U.S. commercial launch vehicle industry. LTV Missile and Electronics Group signed an agreement granting the firm exclusive rights to commercially produce and market the Scout launch vehicle. Conatec, Incorporated, of Lanham, Maryland, signed an agreement facilitating the firm's use of NASA launch facilities at Wallops Island, Virginia. Martin Marietta signed an agreement enabling the firm to gain access to payload processing facilities at the NASA John F. Kennedy Space Center.

In FY 1989, discussions were held with several companies which may lead to cooperative agreements in the future. Two examples are: (1) Unocal (Union Oil of California), which is already engaged in a commercial remote sensing project under a Proprietary Work Agreement with the NASA John C. Stennis Space Center (SSC); and (2) Genentech (a biotechnology firm), working with the Center for Cell Research (Pennsylvania State University), signed a Technical

Exchange Agreement with the NASA Ames Research Center (ARC) and is discussing other possible cooperation.

3. FY 1991 Commercial Use of Space Budget Request. The Commercial Use of Space Program depends on the strategy of leveraging government and industry funds. In the CCDS Program, for example, industry is putting in approximately $2.2 for every $1 that the government contributes. Therefore, any funding reduction from NASA's budget request represents a significant potential loss in industry investment.

NASA traditionally responds to funding or scheduling problems by stretching out the work over a longer period of time. NASA's contractors will stretch their programs accordingly. However, when operating in a leveraged program arrangement, as OCP is, we run a high risk of losing significant amounts of participation and support. Therefore, keeping commitments, not only in budgets, but also in schedules, is essential for carrying out the type of program OCP has established.

For our Program to succeed, we must demonstrate our commitment and continuing support by providing firm flight opportunities. We have mapped out a detailed flight program for these commercial payloads and determined that standard Shuttle flights, including opportunities in the middeck and GAS cans, are not sufficient to meet industry's needs. To help fulfill these requirements, we have initiated efforts to promote the development of alternate means of transportation. ELV's, including sounding rockets, and other commercial payload carriers are required and are included in our budget request of $33.5 million for Commercial Transportation.

In addition to providing transportation for planned CCDS and JEA payloads, the OCP budget request of $76.6 million for FY 1991 Commercial Use of Space will also be used to carry out the following:

a. In Commercial Applications, $38.9 million to include:

(1) Continuing grants to 16 CCDS's,

(2) Providing augmentation which include support in developing research equipment and flight experimentation hardware,

(3) Providing analytical and physical integration required for Space Shuttle payloads flown under JEA's, and

(4) Supporting NASA field installation projects including the Earth Observation Commercial Applications Program at SSC; an improved materials processing in space container at NASA George C. Marshall Space Flight Center; and Commercial Life Sciences Working Group at ARC.

b. In Commercial Development Support, $4.2 million to include:

(1) Studies in international competitiveness,
(2) Economic analysis studies,
(3) Strategic planning,
(4) Support for CPAC, and
(5) Headquarters contractor support:
- Space Station Freedom requirements
- Pricing studies
- Automated data processing support

The required funds can be viewed as a strategic investment in what promises to be an exciting new element of our economy, and a factor in U.S. competitiveness.

TECHNOLOGY UTILIZATION

NASA also fosters commercial interest in space by accelerating transfer and use of NASA-generated technology to private industry. The technology which NASA develops to meet its research and program goals represents an important national resource. The NASA Technology Utilization Program spreads this valuable technology throughout the economy by working with U.S. industry to adapt space technology to meet its needs.

NASA, through this long-standing program, has maintained a systematic approach for identifying space technologies which may have useful application in the nonspace sector of the economy.

Our Technology Utilization Program involves both technology dissemination and technology application. Technology dissemination requires the identification and gathering of information on aerospace technologies making this information available to the private sector. Technology application is the use of these NASA technologies in specific projects for public benefit.

1. Technology Dissemination

a. Industrial Applications Centers (IAC). NASA's network of 10 IAC's is the key component of the technology utilization information dissemination system. Their computerized access to technical information has stimulated significant corporate interest in government-funded or -derived advanced technologies.

IAC's cultivate strong ties with industry, identify industrial client problems and technological interests, and assist their clients through exchange of technological information. IAC's are backed by a score of IAC Affiliates, state-sponsored business or technical centers, that provide access to the technology transfer network. The network now resides in 41 of the 50 states.

b. Computer Management Software and Information Center (COSMIC). In addition to technology, NASA also has developed many types of computer programs which constitute a valuable resource available for reuse. Much of this software is directly applicable to secondary applications and can be adapted to special purposes with little or no modification.

COSMIC is NASA's mechanism for making such programs available to the private sector. COSMIC customers can purchase a program for a fraction of its original cost and get a return many times the investment, even when the cost of adapting the program to a new use is included.

c. AdaNET Software Repository. The AdaNET Software Repository is intended to be a self-supporting commercial organization to provide users of Ada with information sharing and depository services. The objectives of the program are to re-automate the U.S. industrial base; provide an automated, on-line clearinghouse for Ada software; and to provide a reusable Ada software inventory from NASA, Department of Defense, and other resources.

An analysis of Ada user requirements and acquisition of initial Ada library software modules has been completed. We have now entered Phase II of the implementation plan. In Phase II, MountainNET, Incorporated, will, among other tasks, prepare a plan to expand the current University of Houston, Clear Lake, software engineering and Ada data base and incrementally add commercialization support services. The targeted goal is for the AdaNET Software Repository to become self-sufficient by 1991.

d. National Technology Transfer Center (NTTC). The mission of NTTC is to enhance the United States' competitive posture by facilitating the transfer of federally sponsored research and development (R&D) to the private sector. This will be accomplished by providing a nationwide focal point for technology transfer activities, technology and network assistance, linkages to investment and business development sources; and a national forum for developing technology transfer requirements. NTTC will assess the relevance of technology to industry needs and will reduce private sector confusion over access.

A planning and development grant was awarded to Wheeling College, located in West Virginia, on March 1, 1990. The 8-month planning effort will focus on identifying NTTC operational requirements and resource needs. The initial development phase is scheduled to start in July 1990 through a cooperative agreement arrangement.

e. Publications

(1) The publication of *Tech Briefs* is a major element of the technology dissemination program in OCP. This document provides information on NASA research innovations and is distributed monthly to approximately 200,000 members of the U.S. industrial community.

(2) NASA's annual *Spinoff* magazine is intended to heighten awareness among potential users of the NASA-developed technology and the economic and social benefit that might be realized by secondary applications. It describes mainline NASA efforts in major programs that generate new technology and the mechanisms NASA employs to stimulate technology development. Examples of spinoff products in the areas of public safety, the environment, medicine, consumer/home/recreation, computer technology, and industrial productivity are found in *Spinoff 1989*.

2. Significant FY 1989 Technology Dissemination Accomplishments. A recently completed study to assess the economic impacts of NASA technology transfer activities indicated substantial financial benefits to U.S. businesses. The research determined the estimated revenues and cost-savings derived from a sample of applications reported in NASA's *Spinoff* publication.

The study, entitled, *An Exploration of Benefits from NASA "Spinoff,"* traced more than 400 applications reported in the magazine between 1978 and 1986. It was found that 342 applications resulted in acknowledged contributions to sales or savings. Of these, about 75 percent, or 259 cases, permitted some quantification of sales or savings. The 259 applications were determined to have contributed to the sales of new or improved products in the amount of $21.3 billion and contributed to savings of nearly $316 million.

It was also calculated that the revenues produced through the estimated sales generated federal income tax revenues of nearly $356 million. Additionally, 352,000 jobs were projected to have been created, or retained due to the increased revenues (not savings) attributed to these spinoffs. This study

identifies continuing social and economic benefits generated by NASA's technology transfer activities.

3. Technology Application. Technology application is accomplished through interaction with private industries to identify specific needs or problems and provide potential solutions through aerospace-developed technologies. Currently, there are 73 application projects underway at the 9 NASA field installations.

Examples of FY 1990 and FY 1991 technology projects include:

a. Orange, polarizing sunglasses, marketed worldwide, that improve visual acuity and protects the eye from the two most common causes of blindness in the Western World. The original technology resulted from research into the simulation of sunlight and the protection of the human eye in space. This technology has significantly impacted the sunglass industry.

b. Micro Climate personal cooling system (cool suit) for people in occupations where elevated body temperatures can cause fatigue and collapse. Applications from this Moonsuit technology continue to increase and include protection of public service and industrial firefighters, hazardous materials controllers, and for workers in such industries as nuclear power, glass manufacturing, and chemical processing. Another use of this technology application has greatly increased the quality of life for children and other individuals suffering from hypohydrotic ectodermal dysplasia, a disease which eliminates the body's capability of perspiring.

c. A line of contamination control garments used by hospitals, pharmaceutical and medical equipment manufacturers, aerospace and electronic plants, and other industrial facilities where extreme cleanliness is important. The garments, based on NASA contamination control technology, are disposable, which eliminates the costs of laundering and repair, and come in sterile and nonsterile forms.

Many hundreds of major and minor techniques and products developed for the space program have valuable secondary applications. Over the years, NASA's transfer of technology to the private sector has resulted in over 30,000 spin-offs and applications which have resulted in new products, companies, and industries.

Last year, this Subcommittee gave NASA the opportunity to present to them examples of the these technology spinoffs and to demonstrate the far-reaching benefits provided for the American people. We appreciate that opportunity and the interest shown in NASA's technology transfer program.

4. Significant FY 1989 Technology Applications Accomplishments:

a. Stirling Engine. In response to congressional interest, NASA initiated a study in October 1989 to determine whether the Stirling engine technology could be a long-term solution to the Nation's automotive emission problem. The study is also addressing a commercial demonstration as the logical next step; the optimal federal agency long-term sponsor; the distribution of private (and public) financial contributions; and, mechanisms for securing funds. The Departments of Army, Air Force, Energy, and Transportation, and the Environmental Protection Agency are participating in the study. A report is targeted for completion in the spring of 1990.

b. Spinoff Hall of Fame Inductees. In May 1989, the U.S. Space Foundation honored three technology spinoffs that resulted directly from the Apollo Program. The organization hosted a special ceremony at its headquarters in Colorado Springs, Colorado, to recognize the individuals and organizations instrumental in adapting the technology for commercial applications. Three technologies were inducted into the U.S. Space Foundation's Spinoff Hall of Fame and represent but a few of the thousands of technology applications spun off from the Apollo Program. The three technologies are:

(1) Cordless tools developed by Black and Decker as a derivative of specialized tools used by the Apollo astronauts to obtain lunar samples;

(2) Scratch-resistant lenses which use the technology developed for protecting the reflective visors on the astronauts' helmets; and

(3) Fabric structures, like the covering over the Silverdome football stadium in Pontiac, Michigan. The fabric is a derivative of the Apollo spacesuit material.

I am proud that we are continuing progress in the implementation of recent congressional and executive actions aimed at accelerating the transfer of federally funded technology into the private sector. NASA's well-developed program is serving as a model for other agencies as efforts to assist U.S. industrial competitiveness intensify.

5. FY 1991 Technology Utilization Budget Request. In FY 1991, the budget request for the Technology Utilization Program is $24.4 million. These monies will be used to accomplish the following activities:

a. Promote awareness of NASA's Technology Utilization Program and resources available to the public and private sectors;

b. Complete implementation of the AdaNET Program and Phase I of an NTTC Plan;

c. Continued maintenance of the IAC network and its installations to provide for expanded identification of NASA technical capabilities and expertise;

d. Broaden application team responsibilities to assist IAC's in bringing together industrial client problems with existing aerospace technologies; and

e. Improve the capability of the technology utilization offices at the NASA field installations to increase the level of technology transfer activities.

SMALL BUSINESS INNOVATION RESEARCH (SBIR)

While not directly included in this budget request, OCP has management responsibility for the SBIR Program. I would like to take this opportunity to discuss this Program which plays an important role in OCP's commercial development program. SBIR Program objectives, established by law, include stimulating technological innovation in the private sector, strengthening the role of small businesses in federal R&D programs, fostering and encouraging greater participation of minority and disadvantaged persons in technological innovation, and increasing private sector commercial development of innovations derived from federal R&D.

Participating agencies support the SBIR objectives by reserving a statutory percentage (1.25) of their extramural R&D budgets. This reserve is awarded to small business concerns for R&D during the first two phases of a uniform, three-phase process. During FY 1989, the SBIR Program received a substantial increase as part of the overall increase in NASA's R&D funding. This, along with an active outreach program, resulted in an increase in the number of acceptable proposals submitted by small, high-technology businesses.

A recent survey conducted by NASA, and concurred with by the General Accounting Office, indicates that all SBIR objectives are being achieved and that the Program has become a highly regarded element of NASA's overall R&D activities. The survey found that the results of more than half the SBIR projects reviewed have already been incorporated, or will soon be incorporated, into NASA mission programs and that many projects have substantially advanced the technology base in several areas.

The survey revealed that the quality of research conducted in SBIR projects is as high or higher than comparable research funded through other R&D means, and that at least one-fourth of the projects have already resulted in commercial

products or enterprises by the small businesses. NASA data also indicated that a substantial number of minority and disadvantaged firms have won SBIR contracts for high-technology projects.

SBIR activities during 1989 included the selection of 231 Phase I awards from the more than 2,140 proposals submitted in response to the 1989 Program Solicitation. One hundred Phase II awards were made for further development of Phase I projects initiated in 1988.

Outreach activities for 1989 included participation in more than a dozen conferences and seminars aimed at assisting small businesses in understanding the NASA SBIR Program. In an effort to anticipate and encourage winning companies to develop the commercial potential of SBIR results, the SBIR Office has initiated a program to follow and report on projects as they proceed. Other efforts have centered on strengthening ties with NASA's network of IAC's and CCDS's to foster technology transfer and commercial application of NASA technology.

In addition, resource information documents are being made available, including a composite list of all NASA SBIR awards made to date and abstracts of all projects. These will be useful to small businesses interested in participating in the Program and to other firms interested in funding promising developments or in utilizing the results of SBIR projects through licensing, buy-outs, collaboration, consulting, or subcontracting.

SUMMARY AND CONCLUSION

Industry's activities in commercial space have increased steadily and so have the successes. Procuring and launching a commercial sounding rocket, incorporating a company based on CCDS cooperation, and spinning off a technology for a company's use for profit are inspiring events of FY 1989 that encourage us to continue in our efforts to support industry.

The sales figures and tax revenues found in the study on technology utilization can only underscore the importance of that program as well. We

can see that the private sector is eager to receive technology from NASA and can clearly put it to good use for the public good as well as profit generation, which, in turn, generates more taxable income.

The program that is underway in OCP is a well-defined effort on behalf of NASA to encourage industry investment in commercial space. The FY 1991 budget request reflects the need for increased program funding due to the increase in activity in cooperation with industry resulting from FY 1989 and FY 1990 successes. The rewards of these successes will be significant contributions to America's future industrial competitiveness, and provide important economic returns to American taxpayers.

NASA actively supports this Subcommittee's and the Nation's commitment to the commercial development of space. The commercial development of space program has specific objectives for capturing the drive and creativity of the private sector, for increasing NASA's effectiveness in conducting business with industrial firms, and impacting the competitive commercial space market. The partnership between government, industry, and the university community has allowed each to do what it does best. We believe that our approach is comprehensive, vigorous, and forward-looking; and provides the type of organization and structure needed to bring industry into the mainstream of space activities.

NASA

National Aeronautics and Space Administration

Hold for Release Until Presented by Witness

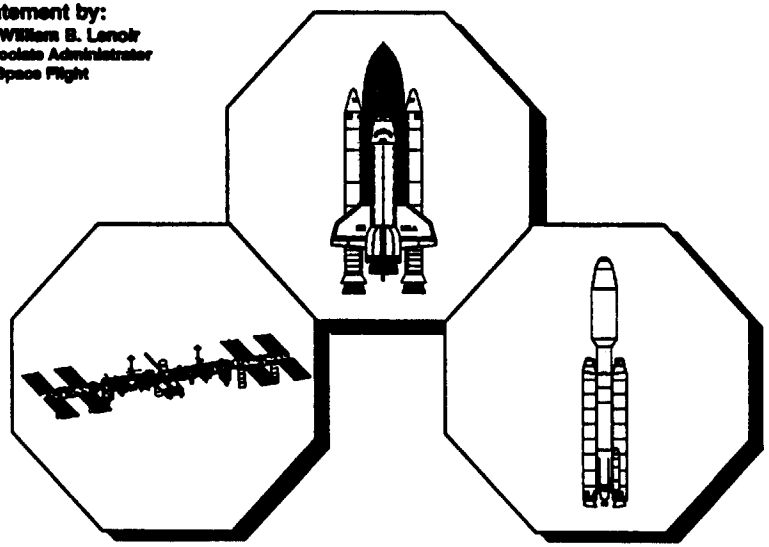
February 21, 1990

Subcommittee on Space Science and Applications

Committee on Science, Space, and Technology

House of Representatives

Statement by:
Dr. William B. Lenoir
Associate Administrator
for Space Flight



101st Congress

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to discuss the Space Station Freedom program.

The mission of the Space Station Freedom program is to develop and operate a multipurpose manned orbital facility beginning in the mid-1990s. We are aggressively moving forward to meet that goal, and our first element launch is now only five years away. 1989 was our first full year of preliminary design activities. Together with our international partners, we made significant progress in designing systems and elements in all areas of the Space Station program. These design efforts were complemented by the fabrication and testing of numerous development hardware articles.

In the last quarter of FY 1989, we conducted a series of configuration/budget reviews to realign the Space Station program with the anticipated near-term funding reduction from Congress. These reviews included participation by all levels of the Space Station program, the user offices at NASA Headquarters, our international partners, and the prime contractors. The program adjustments that resulted from these reviews accommodated Congressional directions for reduced funding, while successfully maintaining both the configuration of the baseline Space Station and the integrity of its capabilities and reducing sources of technical and schedule risk.

Our activities this year are directed at completing the preliminary design of most Space Station systems and elements. We have implemented the program adjustments discussed at the October 31 hearing of the full committee, and we are now preparing for a series of Preliminary Design Reviews (PDR's) later this year. These reviews will culminate with a program-level PDR in December. Our schedule for these reviews is shown on Attachment 1. Our development hardware fabrication and testing efforts continue to support the design process.

This year we are also transferring management of the Polar Platform from the Office of Space Flight to the Office of Space Science and Applications. This decision was made to meet the unique requirements of the planned Earth Observing System (EOS) mission. Transferring the Polar Platform to the Office of Space Science and Applications will ensure maximum responsiveness to the requirements of the EOS user community. We will honor our agreements with our international partners in all respects in the implementation of this transfer.

We have taken steps to strengthen the involvement of users in the development program. The Office of Space Science and Applications, the Office of Aeronautics and Space Technology, and the Office of Commercial Programs are now members of the

Level II Space Station Control Board, in addition to their membership on the Level I Program Control Board. Since these two boards control requirements levied on the work package centers and the program office respectively, the user community has greater and more direct involvement in the Space Station decision process.

Several major studies are in progress to make sure we are effectively spending funds on the needed user capabilities. For example, we are reviewing requirements for laboratory support equipment with the Office of Space Science and Applications and other user offices to determine what equipment is required and which office should develop it.

Our international partners are involved in the management of the program consistent with the international agreements. We are continuing to work closely with them to coordinate our tightly coupled design and development efforts. Together, we have put into place partner liaison offices in Reston and NASA liaison offices at the international partners' sites to provide an effective mechanism for day-to-day communication at the working level of the program. This action complements our frequent meetings between our respective program managers and directors.

Mr. Chairman, the complications that arose from the level of FY 1990 funds appropriated by Congress showed how changes in our budget planning affect not only the U.S. space program, but the programs of our international partners as well. These difficulties underscored the fundamental need for a multi-year appropriation. Our international partnership will stand us in good stead in the critical years ahead, and will be stronger if we can ensure the necessary funding stability for the Space Station.

Looking ahead, FY 1991 will be a key year for the Space Station Program. The preliminary design phase will be completed, and we will move on to detailed design and development activities in preparation for the planned Critical Design Reviews the following year. FY 1992 will mark the start of large-scale fabrication and testing of flight hardware, which will last for several years.

The pace of the Space Station program is driven by our plan to begin assembly in orbit in early 1995, establish permanently manned capability by mid-1997 and to complete the baseline Space Station in mid-1999. The Space Station does depend on maintaining strong national and international commitments to the program, and we are well on our way to making the Space Station a reality.

Full funding for the Space Station in FY 1991 is required to maintain the current program plan. Our current program funding requirements have been reduced to the minimum level

possible, while still meeting our key milestones and international commitments. Another reduction in program funding would again disrupt program planning and progress, and would result in delays in the assembly sequence, deferrals or deletions of program content, or some combination of the two. It would be a grave setback for the Space Station program, for the nation, and for our international partners if another program rephasing were forced by inadequate funding.

FY 1989 ACCOMPLISHMENTS AND FY 1990 ACTIVITIES

Attachment 2 shows how responsibility for developing the Space Station is divided among NASA centers and the international partners.

- Work Package 1 - Marshall Space Flight Center (MSFC), working with Boeing and various supporting development contractors, is responsible for U.S. pressurized modules, associated systems, logistics elements, and payload operations.
- Work Package 2 - Johnson Space Center (JSC), working with McDonnell Douglas and various supporting development contractors, is responsible for the central truss structure, resource node outfitting, various flight systems, crew training, and flight operations.
- Work Package 3 - Goddard Space Flight Center (GSFC), working with General Electric and various supporting development contractors, is responsible for the U.S. Polar Platform and Attached Payloads Accommodation Equipment (APAE).
- Flight Telerobotic Servicer (FTS) - Goddard Space Flight Center, working with Martin Marietta and various supporting development contractors, is responsible for the FTS.
- Work Package 4 - Lewis Research Center (LeRC), working with Rocketdyne and various supporting development contractors, is responsible for the Space Station's power systems.
- The European Space Agency is providing a pressurized laboratory module, the European Polar Platform, and the Man-tended Free Flyer.
- Japan is providing a laboratory module, an exposed facility, and an experiment logistics module.
- Canada is providing the Mobile Servicing System, including the Mobile Servicing Center, Special Purpose Dextrous Manipulator, and maintenance depot.

Let me now address our specific accomplishments of FY 1989 and activities that are in progress during the current fiscal year.

Work Package 1

In FY 1989, MSFC and the Work Package 1 team completed a comprehensive Preliminary Requirements Review. This review established requirements for preliminary design of the U.S. laboratory module, the habitation module, pressure shells and cupolas for the resource nodes, pressurized and unpressurized logistics carriers, the Environmental Control and Life Support System (ECLSS), the internal thermal control system, and the internal audio/video system. All subcontractors for this hardware were selected and brought on board.

Substantial progress was made on the preliminary design of all Work Package 1 elements and systems. Preliminary structural layouts and stress analyses of standard equipment racks, module utility distribution trays, and rack structural attach points were completed. Computer Aided Design systems were used to prepare three-dimensional packaging layouts for many of these items. High fidelity models were evaluated in the Work Package 1 Engineering Development Article, a true size, form, and fit mockup of the pressurized modules. Testing and evaluation of cupola design approaches were completed using this facility to verify viewing capabilities. Quarterly crew station reviews of the U.S. laboratory and habitation module overall layouts were conducted.

The ECLSS comparative testbed was activated. This involved installation of test stands, completion of facility support utilities, and delivery and installation of the air and water regenerative ECLSS subsystems. Testing was performed on units for potable water reclamation, urine processing, and carbon dioxide reduction. Also completed was the integrated air revitalization systems test in the Core Module Integrated Facility, which provided valuable data on subsystems interfaces and interactions, as well as on system-level performance characteristics.

Significant effort in FY 1989 was also devoted to planning for the ambitious ECLSS test program in FY 1990. This includes a test of intra-module air flow characteristics in a Space Station pressurized module, a test of the avionics air and fire suppression concepts, a test of the integrated water recovery system, early systems-level tests of the air revitalization and water recovery subsystems.

Several other subsystem development test programs were initiated to supply data required for the design process. Berthing mechanisms tests were conducted to evaluate a

redesigned alignment guide and to measure berthing loads. Over 80 successful firings were made in the Light Gun Gas Facility to provide data for the preliminary design of the meteoroid/debris shield and the selection of the module pressure shell material. Proof pressure testing of a prototype module yielded valuable data on bulkhead and cylinder deflections. In the internal audio/video system testbed, audio distribution audio recording techniques were simulated. This testbed was then upgraded for systems integration testing of hardware developed by subcontractors. The Software Preliminary Requirements Review was conducted on all Work Package 1 elements and systems, and a Software Production Facility was activated for use in software development. Finally, long lead procurements of Work Package 1 development hardware were initiated.

In FY 1990, the Work Package 1 team is completing preliminary design of its distributed systems. PDRs for these items will be held this year, followed by initiation of final design activities. Preliminary design of all other Work Package 1 hardware will continue.

Comparative testing of ECLSS technology demonstration hardware will be completed. The Phase III ECLSS tests in the Core Module Integration Facility, the Temperature Humidity Control Flow Test and the Concept Confirmation Test will also be completed. The ECLSS pre-development operations systems tests will be initiated. Test activities will continue for the audio/video system and berthing mechanisms. Audio/video system testbed activities will include breadboard testing of selected subcontractor design concepts, and breadboard testing of the distributed wireless audio antenna. Testing will begin on the internal electrical distribution system and hatch mechanisms. Neutral buoyancy tests of manned systems equipment will be conducted. Finally, the initial version of the Space Station payload user's guide is being completed this year.

Work Package 2

In FY 1989, JSC and the Work Package 2 team made substantial progress on the preliminary design of the truss structure, the mobile transporter, various other assembly and external maintenance systems, the propulsion element, the airlock, extravehicular activity systems, the guidance/navigation/control system, the external thermal control system, the communications and tracking system, the data management system, and the Crew Health Care System.

McDonnell Douglas selected Morton Thiokol as the subcontractor for design and fabrication of graphite epoxy tubes for the truss structure. Additionally, testing of the truss structure erectable joint is nearly complete. A single concept has been

selected for the Mobile Transporter structures interface. A full-scale mobile transporter track base and drive hinge assembly has been fabricated, and is being used for harness development and flexibility testing. A concept for the Space Station/Space Shuttle docking system was also developed.

Cupola mockups have been delivered to JSC, and flight crew evaluations of all designs are complete. A one-G mockup of the airlock was completed, and is being used to evaluate crew activity and hardware configurations. Another mockup for use in the water exertion test facility was also delivered. Simulating Zero-G tests have been conducted in the water tanks. Several space suits have been tested in the weightless environment with the Crew and Equipment Translation Aid (CETA) experiment to be flown on a shuttle flight later this year. In addition, some EVA/telerobotic testing was conducted at McDonnell Douglas.

Additionally, deployment of utility trays from a spool was demonstrated in the Water Emersion Test Facility. This simulated deployment will heavily influence the final design. Permeability tests are continuing on line materials and hoses for the McDonnell Douglas baselined non-metallic flexible lines.

The Thermal Ground Test Unit was delivered and installed at JSC. Testing of the thermal bus with heat pipe radiator panels has been completed. The Space Station heat pipe advanced radiator element (SHARE) was tested last year as a Shuttle flight experiment. This flight experiment demonstrated heat pipe isothermality under a thermal load, and revealed weaknesses in an early design of a heat pipe for the Space Station. The results of this test are being used to eliminate this weakness, and two redesigned heat pipes will be tested on the Shuttle's SHARE II mission in early FY 1991.

Proof of concept testing on the rotary fluid coupler was completed. A number of Data Management System (DMS) and Communications and Tracking critical breadboard circuits and models have been completed and are being tested. DMS kit prototypes were delivered to JSC, installed in the test bed, and have completed acceptance testing. In the GN&C area, McDonnell Douglas has selected Perkin Elmer for the star tracker. Fabrication of a space-to-space transceiver modem and video processor breadboard have been completed.

Medical requirements for the Crew Health Care System were baselined, as were specifications for outfitting the nodes and cupola. The environmental health care system mockup was delivered and is being evaluated. In addition, Ford Aerospace was awarded the mission support contract, and Link-CAE was awarded the training support contract.

In FY 1990, the Work Package 2 team is finishing the preliminary design of most systems and assemblies, and will conduct PDRs on these items before initiating detailed design. End item specifications for all systems and elements will be delivered. Procurement of long-lead items is being initiated.

Also this year, ground support equipment for ongoing test activities is being developed and processed. Neutral buoyancy testing of various articles of development hardware and EVA operations will continue. Preparations for the second heat pipe flight experiment on the Shuttle are in progress.

Work Package 3

In FY 1989, GSFC and the Work Package 3 team made considerable progress in the preliminary design of the APAE and various systems for the Polar Platform. Additionally, software development requirements were established, and development of a Software Production Facility was initiated. Documentation covering user design guidelines for on-orbit assembly was developed. Servicing requirements for Space Station payloads were collected and analyzed, and a servicing scenario database was developed for servicing simulations. Finally, preparations continued for the planned Capillary Pumped Loop Flight Experiment on the Space Shuttle.

In FY 1990, the Work Package 3 team will near completion of the preliminary design of its assigned flight hardware elements. Flight hardware development activities will be initiated for the Polar Platform tape recorder and propulsion subsystem after those subcontracts are finalized. The APAE hardware configuration is being finalized, and preliminary end item hardware and software specifications for the APAE and Polar Platform are being completed.

Also this year, testbeds for the development of the platform data system and power system testbeds are being initiated. Fabrication of thermal Flight Experiment hardware is beginning in support of the Capillary Pumped Loop flight experiment, and development of hardware for two other flight experiments is in progress.

Finally, Work Package 3 is being restructured to establish separate schedules and management interfaces for the Polar Platform and manned base APAE hardware in preparation for final transfer of management of the Polar Platform to the Office of Space Science and Applications at the end of this fiscal year.

Flight Telerobotic Servicer (FTS)

In FY 1989, GSFC and its FTS contractors completed Phase B studies, and Martin Marietta was selected to develop hardware

for the FTS and the two development test flights, DTF-1 and DTF-2, planned on the Shuttle in 1991 and 1993. The PDR for the first flight test was conducted last July.

In FY 1990, the FTS team is completing the subsystem design for DTF-1 and will build the hardware for this test flight. The required ground and flight software will also be developed. Initial delivery of the DTF-1 training system and simulator will begin in mid FY 1990. Control documentation for FTS interfaces with the Space Station, the Mobile Servicing Center, and user hardware is also being prepared. Additionally, a plan to actively promote the commercial application of FTS technologies is being developed and implemented this year.

Work Package 4

In FY 1989, LeRC and the Work Package 4 team made substantial progress on the preliminary design of power system components. Component PDRs were completed for the solar cells, battery cells, motor drives, array panel coatings, array bypass diodes, battery simulator, and solar array electrical simulator. Component CDRs were completed for the solar cells and the solar array electrical simulator. The end-to-end architecture of the power distribution and management system was also defined.

The Power Management and Distribution (PMAD) architecture was changed from alternating current to direct current for primary distribution. A common switch design was selected for all secondary switches. Breadboard switches were developed and are being tested at Rocketdyne. Preliminary test results look encouraging. 160 Vdc switches were also tested at LeRC as a part of the supporting development efforts. Construction of the Rocketdyne Space Power Electronics Laboratory facility was completed, and the facility activation was started. Tests of the PMAD control system were conducted, and computer controls were programmed.

Additionally, solar cell production was initiated last year for engineering development and qualification testing. Several hundred cells were delivered from each of two vendors for evaluation. Initial lots of flight-type 8 x 8 cm solar cells were calibrated using high altitude balloon flights. These calibrated cells form the basis for acceptance testing and grading of production solar cells. Fabrication of the solar array electrical simulator was initiated, and photovoltaic array panel/plasma interaction tests were conducted. The tests used 2-panel solar array circuits with a plasma simulating the low earth orbit environment. Results confirmed that the operating voltage of 160v is below the arcing threshold. The test also showed the array ground is not a driving factor in determining the primary distribution

ground scheme. The dynamic electrical response of the solar array circuit was also tested.

Rocketdyne also developed and tested the Radiant Fin Heat Exchanger concept for ORU box cooling. The radiant fin concept provides heat transfer without requiring tight mechanical mating of flat plates as required in more conventional approaches. This approach facilitates ORU removal and replacement by robotic means. The final delivery of NiH2 cells was placed on life test at NASA LeRC. A total of 39 cells of various designs from three manufacturers were placed on test, and 3,500 cycles were achieved by the end of FY 1989. These results will be factored into the final selection of SSF cell design parameters. Two NiH2 cell vendors also completed a nickel electrode optimization program and electrode testing is in progress.

Construction of the Power Systems Facility was also completed, and a full-scale prototype solar dynamic concentrator was received for testing in this facility. The tests increased confidence that a solar dynamics concentrator can be aligned on earth, disassembled, and then reassembled in orbit without realignment. 10,000 hours of test were completed on the solar dynamics receiver to demonstrate compatibility of the thermal energy storage salt with the containment vessel. Also, tests on a single receiver tube with energy-storage canisters verified the thermal energy storage concept used in the baseline solar dynamics system receiver design.

In FY 1990, the Work Package 4 team will near completion of the preliminary design of its flight hardware elements. Detailed design of hardware and software for the power management and distribution system will begin. Fabrication of breadboard components of this system will be completed, and testing will be initiated. Detailed design of the photovoltaic module will begin, and development testing of its assemblies and components will continue.

Also this year, fabrication of engineering models of the battery and DC electronics will begin. Neutral buoyancy testing of the photovoltaic module beta gimbal and the solar dynamic concentrators 3-panel assembly is being initiated.

Operations and Utilization Capability Development

The objective of the Operations/Utilization Capability Development (OUCD) program is to develop the operational ground facilities, systems, and capabilities required to conduct Space Station ground and flight operations.

In 1989, OUCD activities focused primarily on design of facilities. Kennedy Space Center conducted the CDR for the Space Station Processing Facility, and initiated procurement

of the Test, Control, and Monitor System. Marshall Space Flight Center began design of the Payload Operations and Integration Center and the Payload Training Center. Johnson Space Center began design of the Space Station Control Center and Space Station Training Facility. Design of Engineering Support Centers at all four work package centers was also initiated.

In FY 1990, Kennedy Space Center is procuring computer-aided design and engineering equipment, continuing design of the Test, Control and Monitor System, and procuring equipment for outfitting the Space Station Processing Facility. Marshall Space Flight Center is continuing design of the Payload Operations Integration Center and the Payload Training Center, and is continuing development of payload analytical integration software tools and processes. Johnson Space Center has completed design of the Space Station Control Center, the Space Station Training Facility and the Space Systems Automated Integration and Assembly Facility. Construction of these facilities will be initiated. Johnson is also continuing operations assessments, contingency scenario analysis, and operations requirements development. Operations support contracts have already been awarded this year. In addition, all four work package centers are continuing design of their respective Engineering Support Centers.

Over the past year, considerable progress has also been made in determining roles and responsibilities of the NASA centers and international partners during mature operations. Functional Control Documents have been drafted to define the support structure required at each center and international partner to implement each of the key operation and maintenance functions. The NASA centers and international partners have participated in two joint reviews of these documents.

Management and Integration

We have also thoroughly reassessed our program management approach, and have made some improvements in our development organization. The Space Station management team has been strengthened by the addition of some of NASA's most experienced managers from the Space Shuttle program. The Level I organization at NASA Headquarters has been modified as a result of the Office of Space Station merging with the Office of Space Flight. This merger was undertaken to ensure that NASA's manned space flight programs are completely coordinated.

The Space Station Freedom Program Office (Level II) has been modified to increase the efficiency and effectiveness of its management and integration role in the program. Level II system and element integration has been co-located with the two largest Work Packages, Johnson Space Center and Marshall

Space Flight Center. A major consideration in this decision was that the experienced technical talent we require is more readily available at these two NASA centers.

Level II is responsible for program control, integration, systems engineering, and operations/utilization integration. Contractors for these efforts include Grumman for the Space Station Engineering and Integration Contract (SSEIC), Lockheed for the Software Support Environment (SSE), and Boeing for the Technical and Management Information System (TMIS).

In FY 1989, program engineering and integration activities focused on resolving issues raised in the previous year's Program Requirements Review, and on developing data needed to support preliminary design efforts at the work package centers. Level II also carried out a detailed technical audit of the program content in each work package against program level baseline documents. In preparation for the upcoming series of PDR's, Level II made significant progress in establishing an automated requirements management capability and in refining program engineering analysis tools and processes. Associate Contractor clauses were incorporated in the prime contracts to facilitate direct integration of hardware and software schedules between the four prime contractors.

Level II, supported by the Space Station Engineering and Integration Contractor (SSEIC), progressed toward completion of the requirements for the manned base and polar platform flight and ground systems, including critical resource allocations for weight and electrical power. System engineering analyses were performed and major design trade offs were conducted which resulted in a revised baseline assembly sequence and key functional requirements for the stages of assembly. The results of these accomplishments in FY 1989 provided the basis for stage definition of selected stages in FY 1990.

Also in FY 1989, the TMIS development organization created a program-wide electronic mail, calendar, and file transfer capability that now links the NASA electronic mail system with the Space Station contractors and the international partners. Computer programs were developed to assist in document control, assembly sequence/resource allocation, action tracking, and other tasks. In addition, development work was initiated on the Computer Integrated Engineering capability, a tool to enhance program design integration. SSE accomplishments in FY 1989 included delivery of Software Production Facility components to the work package prime contractors, and definition of the standard software development architecture for SSE host computers and work stations for all work package contractors.

In FY 1990, the Space Station Freedom Program Office, with the support of SSEIC, will perform analysis related to the overall configuration and assembly sequence, system architecture, and performance requirements. Allocations of power, weight, and other resources are being baselined. Integrated preliminary design will be accomplished on the manned base and key stages of assembly. The SSEIC will play a significant role in supporting the Space Station Freedom Program Office with the planning of, participation in, and support of the Space Station Freedom Program's Preliminary Design Review process which is a major Program milestone to be completed in December 1990. Additionally, work will be accomplished on an end-to-end integration plan, a multilateral utilization study and a trial payload manifest.

TMIS will establish engineering databases, develop technical applications, and implement the program-wide drawing and model library. These applications and databases, along with the Computer Integrated Engineering System, will be utilized heavily during the Program's design phase. In addition, TMIS will provide critical data processing support to the Preliminary Design Review. The SSE contractor will outfit additional Software Production Facilities at selected subcontractor locations, will deliver numerous software development tools and documentation standards, will complete the next SSE Operational Increment, and will install an integrated environment for software development, test and verification.

Transition Definition

Transition Definition activities ensure that the baseline Space Station can evolve consistent with projected user requirements, national space policy, our international agreements, and program constraints. Advanced System Studies are undertaken to define Space Station capabilities required to support anticipated future needs and missions such as the Human Exploration Initiative. Advanced Development tasks are focused on applying automation and robotics technologies to improving productivity and reducing future operations costs. These activities are essential to ensure that critical hooks and scars are provided in the baseline to enable evolution to meet future requirements.

In 1989, Advanced System Studies tasks identified preliminary reference configurations for baseline Space Station evolution and recommended associated design provisions and technology requirements. Possible revisions to the baseline Space Station were analyzed as part of the configuration/budget review process. Study support for the Human Exploration Initiative is beginning. Advanced Development tasks focused on demonstration of advanced automation applications for status monitoring, fault detection and isolation for Space Station flight and ground systems. Performance enhancements

for FTS control algorithms were also made. Strong emphasis was placed on automation and robotics technologies that could reduce manned extravehicular and intravehicular activities during assembly and early Station operations.

Pending funding approval, in FY 1990, Advanced System Studies tasks will build on the knowledge gained of both maturing system designs and requirements posed by identified evolution requirements. Design requirements and accommodations ("hooks and scars") for distributed system capacity growth and new technology insertion will be identified. Advanced Development tasks will continue to emphasize advanced automation, robotics, and other technologies to improve flight and ground system productivity and to reduce long-term operations costs. Continued development and demonstration on Space Station engineering testbeds will refine design accommodations to enable increased use of automation and robotics in both the baseline and evolutionary Space Station.

International Partners' Activities

In FY 1989, NASA and the international partners moved forward in a number of areas. The Phase C/D/E Memorandum of Understanding (MOU) between NASA and the Government of Japan entered into force in 1989 (MOUs with ESA and Canada entered into force in 1988). Japan also selected the hardware development contractors for the Japanese Experiment Module (JEM), and conducted its preliminary requirements review for this module.

The European Space Agency (ESA) began evaluating responses to its space segment industrial proposal, and began preliminary definition of its ground infrastructure requirements. ESA also conducted parallel studies of two polar platform concepts and selected its baseline concept.

Canada completed the preliminary design of the Mobile Servicing Center and conducted a PDR before moving into detailed design activities.

In FY 1990, NASA and its partners plan to establish, under the Multilateral Coordination Board, two panels called for under the agreements to coordinate long range planning for Space Station utilization and operations. We will also complete initial baselining of joint design and development requirements documentation. All the partners will participate in the Space Station program-level PDR. Canada will conduct a joint Mobile Servicing Center PDR with us. Japan will be conducting its PDR for the JEM, in addition to initiating Phase C/D contractor activities. ESA will finalize its Phase C/D contractor approach.

Space Station User Activities

As a world class research laboratory in space, Space Station Freedom will offer users unparalleled opportunities for space science and technology research. Facilities in the pressurized laboratories will support extensive microgravity and life science research, while attached payloads will offer research benefits to many science and technology disciplines.

Space Station Freedom's diverse user community is refining its plans to conduct life sciences research. By the end of FY 1991, NASA's Office of Space Science and Applications will complete definition studies on the space Biology Initiative, and will begin its full development phase. This project provides for U.S. facilities on the space Station dedicated to space physiology, gravitational biology, exobiology, and closed ecological life support system testing and research. Users will continue definition of a centrifuge facility that will provide variable gravity and one-gravity control capabilities for in-flight experimentation. Definition activities are beginning on the Biomedical Monitoring and Countermeasures initiative, which will help us develop techniques to maintain optimum crew health and performance during extended stays on orbit. The Spacelab Life Sciences (SLS-1) mission in 1990 will be the first in a series of Shuttle/Spacelab missions dedicated entirely to life sciences, and will focus on investigation of biomedical responses to weightlessness.

The Space Station's microgravity environment will allow users to conduct unprecedented experiments in the areas of material, fluid, and combustion science. Definition of several facilities for this research is the primary user-related activity this year. These definition activities focus on facilities for: heating, biotechnology, modular combustion, fluid physics and dynamics, advanced protein crystal growth, and modular containerless processing. Meanwhile, final preparations are underway for the first International Microgravity Laboratory Spacelab mission in December. This is one of the many precursor flights on the Shuttle that will allow the user community to further refine technology and research facility requirements for Space Station utilization.

Finally, through the use of attached payloads, Space Station Freedom will offer opportunities to make extended measurements and observations to a variety of other disciplines, while offering the capability for servicing on-orbit. Space Station user activities during 1990 focus on continuing definition of end-to-end science operations requirements and on providing Space Station designers with appropriate levels of information regarding science requirements. Definition studies will continue for candidate attached payload instruments selected in 1989.

FY 1991 RESEARCH AND DEVELOPMENT BUDGET REQUEST

Space Station Freedom's Research and Development (R&D) funding requirements for FY 1991 and the following two years reflect the progress being made in the development program. The detailed design phase of the program begins in FY 1991, and development hardware fabrication and testing activities must accelerate accordingly to support CDR's in the following year. Also, key ground facilities required for testing, training, integration, and control must be completed in order to support schedule. The request supports the planned growth in the development effort to stay on track for beginning assembly in orbit in March 1995.

The Space Station's funding requirement in FY 1991 is $2.451 billion. Additionally, we are requesting a three year advance authorization and appropriation that would also provide $2.907 billion in FY 1992 and $3.031 billion in FY 1993. This legislation would greatly increase programmatic stability, provide continuity of the development process, and protect the integrity of our commitments. Our request is consistent with the proposed development cost ceiling of $13 billion in 1984 dollars.

The chart on the next page shows how the FY 1991 Space Station budget request is broken down by program area. There are two significant differences between this budget request and previous requests. First, beginning with FY 1991, the Space Station budget no longer contains funding for the Polar Platform project. Second, this request contains, for the first time, funding for Human Exploration Initiative study activities in the Advanced Programs budget line. These activities will examine Space Station capabilities and technologies that may be required to support manned missions to the Moon and Mars.

ACTIVITIES SUPPORTED BY FY 1991 R&D FUNDING

Let me now discuss our specific plans for FY 1991, and what we must accomplish to maintain our first element launch milestone in early 1995.

Work Package 1 ($522 million)

In FY 1991, the Work Package 1 team will be heavily involved in the final design of its distributed systems in preparation for their CDR in early FY 1992. The preliminary design of the U.S. laboratory module will be completed, its PDR will be conducted, and final design activities will begin in preparation for a CDR in FY 1992. Engineering manpower for design and analysis activities will increase to support the FY 1992 PDRs for the habitation module and logistics carriers. Other key activities include procurement of hardware for

FY 1991 R&D Budget Request for Space Station

(Amounts In $ Millions)

Work Package 1	522
Work Package 2	873
Work Package 3	34
Flight Telerobotic Servicer	106
Work Package 4	368
Total Work Packages and FTS	1,903
Operations/Utilization Concept Development	255
Management and Integration	248
Advanced Programs	
- System Studies and Advanced Development	16
- Human Exploration Initiative	20
Operations	9
Total FY 1991 R&D Budget Requirement	2,451

development and qualification testing of the Environmental Control and Life Support System (ECLSS), and testing of the integrated ECLSS subsystems in a simulated module. Structural test articles for the nodes and cupolas will be fabricated and used to conduct structural loads and environmental tests.

Supporting development activities at Marshall Space Flight Center include providing test facilities and related support (such as meteoroid/debris protection testing, seal development, berthing mechanism testing, module pressure/structural testing, and environmental testing) for prime contractor development efforts. Also included are ECLSS systems analyses, supporting development testing and simulations, and materials properties assessments, including metallurgical support and lubricant evaluation. Other planned supporting development activities include systems engineering and integration, as well as implementation of a comprehensive technical and management information system.

Work Package 2 ($873 million)

The Work Package 2 team will focus on the CDR for the Data Management System in support of the first delivery of a data management system kit in FY 1991. Engineering development units for the assembly work platform, the mobile transporter, the astronaut positioning system, the communications and tracking system, the hyberbaric hatch, and the thermal control system will be delivered. Testing of these units will be conducted to support the program CDR the following year. Engineering design and evaluation of the guidance, navigation, and control system, mechanical systems, and other systems will continue.

Supporting development activities will continue in preparation for the CDR. At Johnson Space Center, supporting development provides for all the test and facility manpower required for independent analytical support to assess system design viability, test article outfitting, and testbed operation. For example, supporting development activities for the truss assembly will include integrated loads and dynamics analysis, structural testing, materials usage assessment, structural assembly and berthing verification, and hypervelocity impact testing. The manpower, laboratories, computational capabilities, and hardware required for these analytical tasks will be supplied by supporting development contractors.

Work Package 3 ($34 million)

After the Polar Platform is transferred out of the Space Station program, the primary item remaining in this work package is the Attached Payloads Accommodation Equipment (APAE). The preliminary design of the APAE will be completed, the PDR will be conducted, and detailed engineering design and analytic work will begin.

Goddard Space Flight Center's supporting development activities include defining APAE common equipment, providing data support services and technical discipline support to structural/thermal analysis, defining contamination and monitoring requirements, and performing risk assessments.

Flight Telerobotic Servicer (FTS) ($106 million)

The major FTS activity next year will be integration and launch of the first development test flight on the Shuttle. The primary objective of this test flight will be to evaluate the FTS design and man-machine interfaces through the use of a manipulator system, a preliminary workstation, and software. DTF-1 hardware and software testing will receive particular emphasis, and astronaut training on the DTF-1 training system and simulator will begin after completion of checkout. PDR's for the second development test flight and the FTS itself will also take place, and FTS components will undergo continued development and test.

Supporting development activities include development of equipment for crew training, flight operations support, and integrated flight simulations. Efforts will continue on applications procedure development and studies supporting potential enhancements.

Work Package 4 ($368 million)

The Work Package 4 team will continue work on the development and qualification of the solar cells and blankets. Energy storage assembly qualification cells will be fabricated and tested. Detailed design and testing of module items such as electrical equipment assemblies and beta gimbals will continue. Power management and distribution (PMAD) system components and orbital replacement units will undergo detailed design during FY 1991. End-to-end testing of PMAD components will be completed in late FY 1991, and hardware will be delivered to Lewis Research Center in preparation for the electrical system integrated test planned the following year.

Supporting development activities include independent verification of the prime contractor systems engineering and integration efforts. Also included is the provision of a facility to conduct electrical integrated testing, "fleet leader" battery testing, and system validation of the photovoltaics module.

Operations/Utilization Capability Development ($255 million)

Johnson Space Center will complete requirements definition and design of the Space Station Training Facility and the Space Station Control Center. Construction of these facilities will begin, with the objective of having them ready in 1993.

Related hardware and software acquisition activities will also begin. Software development activities of the operations planning and analysis system will continue at an increased pace.

Marshall Space Flight Center will define design and operations requirements for the Payload Operations Integration Center to provide an initial operational capability in 1995. A request for proposals will be released for systems development and procurement of the Payload Training Center, which is scheduled to have an initial operational capability in 1995.

Kennedy Space Center will begin significant equipment purchases, and will increase activity in planning, scheduling, systems software development, and manpower buildup for the Test, Control, and Monitor System (TCMS) and the Space Station Processing Facility. The TCMS PDR and the logistics information system CDR will be completed. Requirements for the Space Station Hazardous Processing Facility will be baselined.

Level II will refine facility requirements for Space Station operations and utilization in the Functional Control Documents, which will provide a basis for coordinating operations and utilization planning activities of the NASA centers and international partners.

Management and Integration ($248 million)

Management and integration activities will continue to focus on engineering integration, expansion of the Software Support Environment (SSE), and expansion and operation of the Technical and Management Information System (TMIS).

The Space Station Engineering and Integration Contractor (SSEIC) will assist NASA in a broad range of activities required to prepare for completion of the program PDR in December 1990 and the CDR in FY 1992. These system engineering tasks include top-level stage definition for key stages of assembly, analysis of stage performance and assessments of the design against the requirements. The system integration tasks include integrated scheduling and development of verification plans, engineering data bases, and interface control documentation. Program plans will be developed for system safety and quality assurance, launch package integration, on-orbit assembly and checkout, and integration with the Space Shuttle. The SSEIC will have an increased role at the field centers based on the relocation of the systems and element integration responsibilities to JSC and MSFC. For example, the SSEIC will support the Level II offices at these centers in preparing and maintaining Interface Control Documents, Architecture Control Documents, and Baseline Configuration Documents.

The SSE operational capabilities will be expanded by increasing and improving existing capabilities in the Software Support Environment Development Facility and the Software Development Facilities at contractor sites. In FY 1991, the Software Production Facilities at the field sites will be supported and additional facilities put in place as required.

Incremental delivery of TMIS products will continue. Efforts will continue toward completing electronic bridges needed to link together contractors, NASA centers, and domestic and international users. Technical and resource information management, tracking systems, and databases will continue to be developed, with emphasis on those elements required to support the program PDR and CDR.

Advanced Programs ($36 million)

In FY 1991, Advanced Development and Advanced System Studies activities will ensure that the baseline Space Station will have the capability to add new functions, expand planned resources, and avoid obsolescence through technology upgrades. Advanced Development tasks will continue to emphasize advanced automation, robotics applications, and technology development to improve flight and ground system productivity and reduce long-term operations costs. Activities planned include: demonstration of knowledge-based automated subsystem control for flight and ground systems applications and cost effective software test/integration; and, demonstration of FTS operator/robot shared control in support of both the DTF-1 flight experiment, and the demonstration of large robot control from a remote site. Advanced System Studies will continue definition of an evolution reference configuration, including analyses to identify baseline configuration impacts and operational compatibilities associated with the more capable Station. Continued analyses are planned of the Station's distributed systems to define and document critical evolution design requirements before hardware construction.

The Human Exploration Initiative will likely evolve Space Station Freedom beyond its baseline configuration capabilities. Supporting potential transportation requirements may necessitate additional structure, power, servicing, and other capabilities. $20 million of the Advanced Programs request is for exploration technology to begin to study systems-level enhancements, and to begin the advanced development and preliminary design of the following crucial systems: Space Station-based EVA and high pressure suits; solar dynamic power; expanded hybrid power distribution and management system; and advanced propulsion. A special study on concepts of advanced automation and robotics for potential space transfer vehicle assembly, checkout, and servicing will be initiated to determine an appropriate mix of automation and EVA that may be needed to support potential

mission operations. The focus of these efforts will be to ensure that the essential hooks and scars to support HEI are identified and incorporated into the baseline program. Planning for these activities is being closely coordinated with the Exploration Technology program.

Operations ($9 million)

FY 1991 is the first year for funding operations. The early operations activity includes the establishment of a logistics system and spare parts for the flight systems. The FY 1991 funding in this area will allow for the procurement of long-lead materials required to begin establishing the spares inventory. These procurements need to be initiated in FY 1991 to ensure that spares are available to support launch site processing as well as on-orbit operations for early assembly flights. As the Space Station Program moves into its operational phase, the operations budget will provide for sustaining engineering, logistics, crew training, hardware processing, and other operational costs.

OTHER BUDGET REQUIREMENTS

Research and Program Management

NASA's Research and Program Management (R&PM) budget funds the salaries of NASA personnel assigned to the Space Station program. This area of the budget also supports our travel requirements, which are considerable due to the wide geographic dispersion of the program, including the international partnership. Consistent with the increasing pace and scope of program R&D activities, NASA requires increases in both R&PM funding and the manpower ceiling for the Space Station program. As the efforts of the Space Station contractors expand, NASA direction and oversight must also grow to ensure that R&D funds are spent wisely and efficiently.

Construction of Facilities

Several projects in the Construction of Facilities (CoF) budget are critical to the Space Station program. In 1991 we will begin construction of the Space Station Processing Facility at Kennedy Space Center and the Neutral Buoyancy Laboratory at Johnson Space Center. We will also continue construction of the Space Station Control Center, and complete construction of the Space Station Training Facility at Johnson. Full funding for these facilities is essential to support our plans to begin Space Station launch and assembly operations in early 1995.

Assured Crew Return Vehicle

NASA's Space Transportation Capability Development R&D request for FY 1991 includes funding for Phase B definition studies of an Assured Crew Return Vehicle (ACRV) for the Space Station. The ACRV definition studies are required to support future decisions on its use with the Space Station.

KEYS TO SUCCESS IN FY 1991

- Funding Adequacy and Stability - Implementing our plan to begin assembly in early 1995 and complete the baseline Space Station by mid-1999 depends on maintaining an adequate and stable funding profile. At the very least, inadequate funding would disrupt the development effort, delay our schedule, and increase program costs.

- Preliminary Design Review Schedule - The program will be conducting more than 80 subsystem PDR's in 1990 leading up to a system-level PDR in December 1990. The intensity and manpower requirements across the program will be focused on this accomplishment.

- Systems Engineering and Integration - The program will define and baseline element-to-element interfaces and element-to-distributed system interfaces Baseline Configuration Documents will define hardware locations within modules and on the truss structure. Functional Control Documents will define the flight-to-ground system architecture. Architecture Control Documents that were baselined last fall will continue to be updated as necessary to reflect approved changes in the upcoming PDRs.

- Resource Control - Weight and power controls were baselined at the work package level last fall. Continued assessment of these controls and baseline control of crew time and volume will occur this year.

- Debris Protection - Debris protection criteria will be baselined and reflected in the PDR this year. In addition, a debris protection plan will be developed that minimizes the likelihood of debris impact for objects larger than the design criteria selected.

SUMMARY AND CONCLUSIONS

In closing, I would like to emphasize four key points.

First, our objectives for Space Station Freedom have not changed. For our science program, Freedom offers a laboratory for research in many scientific disciplines and a platform for

instruments to look out at the universe as well as back toward the Earth. For technology development, Freedom will be a unique national facility - a testbed for evaluating technologies, procedures, and design approaches for potential application in future space systems. For our exploration program, Freedom's manned base represents the establishment of a permanently manned oupost in space and a stepping stone for the missions of the future.

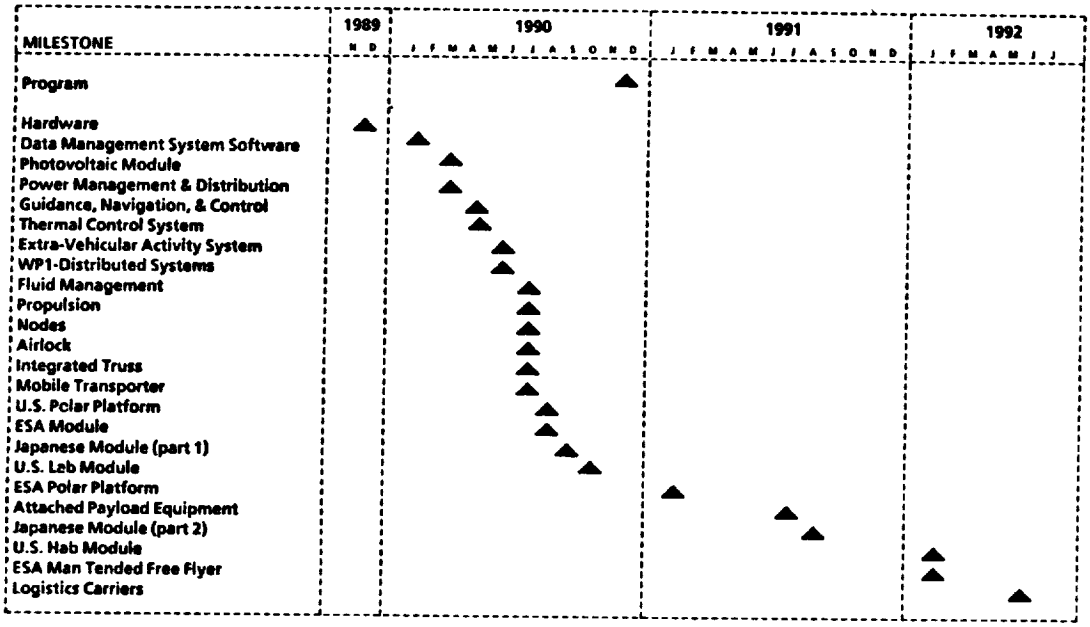
Second, our progress to date on the Space Station has been substantial. The First Element Launch milestone is one year closer now than it was at our last budget hearing before this Subcommittee, and our design and development effort is moving forward accordingly on all fronts. The Space Station is developing hardware and necessary infrastructure. Many of our important accomplishments to date involve tangible hardware items, including hundreds of breadboards, proof-of-concept development items, testbeds, test articles, mock-ups for human factor analysis, and technology demonstration hardware.

Third, some program adjustments have been required in the last year, but the basic integrity of the Space Station program is intact. The reduced funding for FY 1990 and the resulting need to minimize near-term program costs, technical risks, and schedule risks forced some changes in program plans, primarily involving the schedule for outyear assembly milestones and addition of planned capabilities. Despite these recent adjustments, however, the fundamental objectives of the Space Station program are unchanged, and the planned capabilities of the Space Station are maintained.

Finally, as you well know, full funding for FY 1991-1993 is necessary if we are to avoid additional disruptions in the Space Station development effort. The stability that is required can only be provided by multiyear funding. This Committee has understood this reality and demonstrated its strong support for the program by approving the Space Station's existing multiyear authorization. Renewal of this multiyear authorization and initiation of a multiyear appropriation are essential if we are to complete the baseline Space Station before the start of the twenty-first century.

Mr. Chairman, this concludes my prepared statement. I look forward to answering your questions.

SPACE STATION
PRELIMINARY DESIGN REVIEWS



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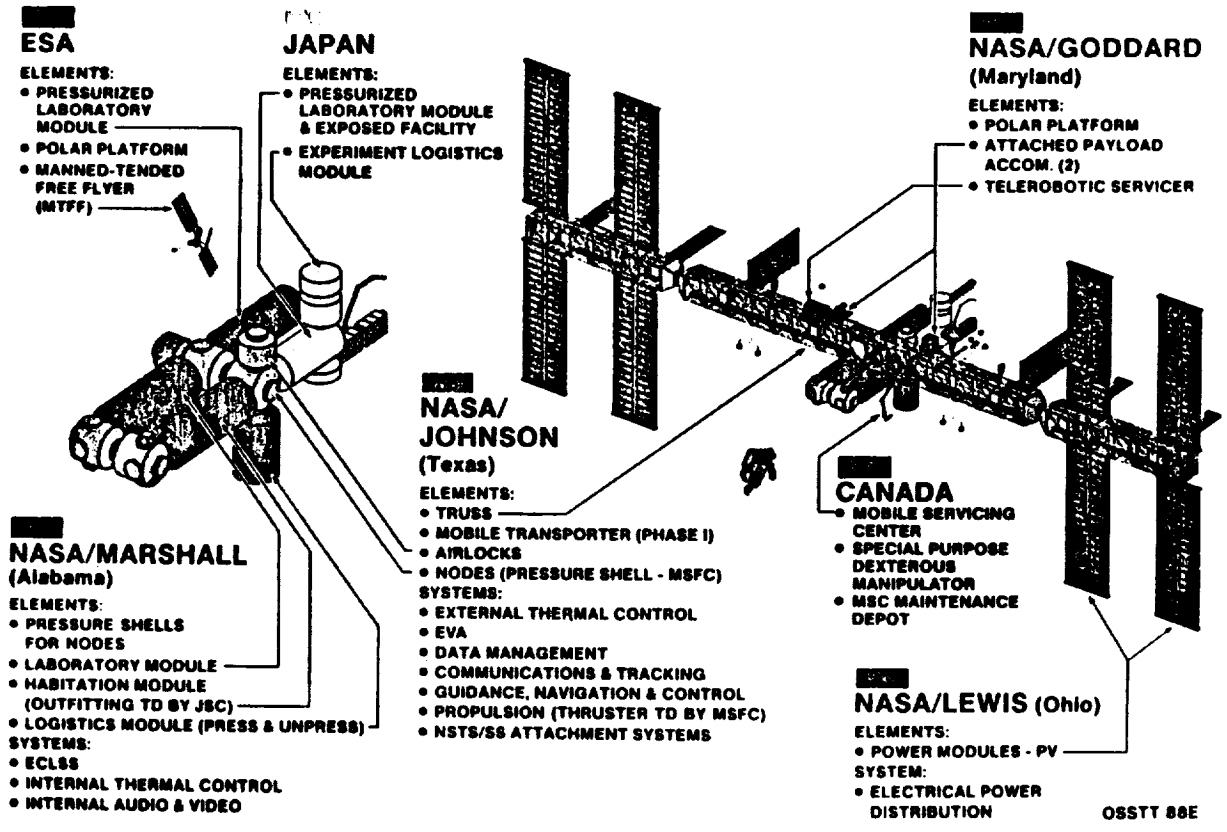
SPACE STATION FREEDOM



Attachment 2

NASA
National Aeronautics and Space Administration

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Presented by Witness

March 26, 1990

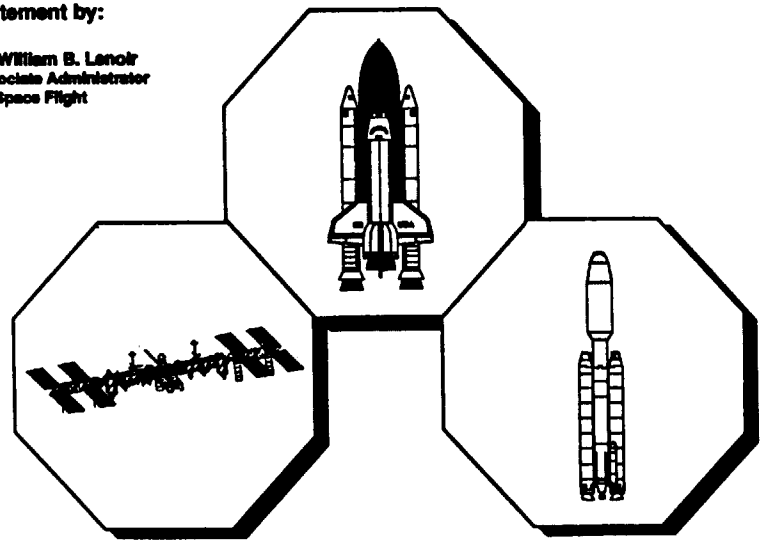
Subcommittee on Science, Technology and Space

Committee on Commerce, Science and Transportation

United States Senate

Statement by:

Dr. William B. Lenoir
Associate Administrator for Space Flight



101st Congress

HOLD FOR RELEASE UNTIL PRESENTED BY WITNESS

Statement of

Dr. William B. Lenoir
Associate Administrator
Office of Space Flight
National Aeronautics and Space Administration

before the

Subcommittee on Science, Technology and Space
Committee on Commerce, Science and Transportation
United States Senate

Mr. Chairman and Members of the Subcommittee:

As I review our FY 1991 budget, I hope to convey the spirit of enthusiasm and purpose which permeates the Office of Space Flight. We enter this new decade with new leadership and renewed determination. We look forward to a future of technological achievement, economic growth and opportunity, and reassertion of United States leadership and preeminence in space. So it is with great pride and optimism that I report to you today on our fiscal year 1991 budget objectives.

As you are aware, space flight is unforgiving of error. Accordingly, we are extremely proud of our launch record. In January Columbia successfully deployed the SYNCOM-IV satellite and retrieved the Long Duration Exposure Facility on a flight of record-setting duration. Atlantis accomplished a classified Department of Defense mission in February. Early next month Discovery is scheduled to carry the Hubble Space Telescope to orbit. It will be our fifth launch in seven months — an achievement which testifies to the Shuttle program's steady and deliberate buildup of its flight rate. Also during 1989, we flew two successful Expendable Launch Vehicles (ELVs) and three upper stages. A great deal of behind-the-scenes efforts in many diverse areas contributed to these launch successes. The sum of these is far too complex for detailed discussion in this forum, but the thousands of working men and women in government and industry who share in this accomplishment deserve our warmest commendation.

Space Station Freedom program activity during 1989 included extensive tests on hundreds of hardware items in all four work packages. Accomplishments ranged from activation of the Environmental Control and Life Support System (ECLSS) comparative testbed and testing of all the ECLSS subsystems, to initiation of solar cell production for the photovoltaic power system. We have begun the ambitious series of system-level Preliminary Design Reviews (PDRs), and anticipate completion of the program-level PDR in December — a milestone of great significance. Also during 1989 we completed an extensive design phase revision which produced a more streamlined, cost-efficient program. The program has also benefited from the

infusion of experienced managers from the Space Shuttle program. Finally, an organizational realignment has brought the Space Station and Space Shuttle programs closer together to assure their harmony, and installs more explicit lines of authority and responsibility. Our working relationship with the international partners has been strengthened by day-to-day communications at the working level of the program, complemented by frequent meetings between our respective program managers and directors.

SPACE FLIGHT FY 1991 BUDGET REQUEST

We are resolved that this budget be dedicated to sustaining the safety and mission success which we presently enjoy, and to moving forward toward the challenges and opportunities which await us. I shall discuss the highlights of this budget in the context of our resolution to achieve the proper balance of ardor, prudence, and fiscal responsibility.

The Office of Space Flight's FY 1991 budget request includes $4,420.6 million under the Space Flight, Control and Data Communications (SFC&DC) appropriation, and $3,224.3 million under the Research and Development (R&D) appropriation; $773.4 million for Space Transportation Capability Development, and $2,450.9 million for Space Station. In FY 1990 our corresponding budget is $3,580.5 million in SFC&DC, $562.4 million in Capability Development, and $1,749.6 million for Space Station. In addition, our current budget plan for FY 1990 includes a $175 million undistributed reduction in SFC&DC as the result of appropriation actions. The agency plans to resolve this unfunded requirement later in the year. Additionally, Space Station's funding request includes a three-year advance authorization and appropriation that would provide $2,906.9 million in FY 1992 and $3,031.3 million in FY 1993. Multi-year funding is necessary to greatly increase programmatic stability, provide continuity of the development process, and protect the integrity of our commitments. This request is consistent with the proposed development cost ceiling of $13,000 million in 1984 dollars.

With this FY 1991 budget level and its runout, we support buildup of the Space Shuttle flight rate to 12 flights per year beginning in 1994, the buildup of flight activity for ELVs, a related increase in payload support activities (primarily in Spacelab and Payload Operations), and the buildup in the Advanced Solid Rocket Motor (ASRM) program as it begins its first full year of development. The FY 1991 budget also supports an increase in propulsion technology development activities for the President's Human Exploration Initiative. The SFC&DC request is divided into two elements -- $1,302.0 million for Shuttle Production and Operational Capability, and $3,118.6 million for Space Transportation Operations. The R&D request is divided into two elements — $2,450.9 million for Space Station and $773.4 million for Space Transportation Capability Development.

Programs and activities funded under these categories are:

* SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY -- provides the capability to fly safely at the projected flight rates. Funding is provided for Orbiter Operational Capability, including the Extended Duration Orbiter and Structural Spares; Propulsion Systems, including the Advanced Solid Rocket Motor (ASRM); and Launch and Mission Support.

* SPACE TRANSPORTATION OPERATIONS -- supports procurement, processing and services to the mixed fleet launch capability. Funding is included for Shuttle Flight Operations, Shuttle Flight Hardware, Shuttle Launch and Landing Operations, and commercial ELV launch services.

* SPACE TRANSPORTATION CAPABILITY DEVELOPMENT -- provides for effective use of and extensions/improvements to our operational capabilities. Funding is included for Spacelab development and operations, Upper Stages for both Shuttle and ELVs, the necessary Engineering and Technical Base (ETB), Payload Operations and Support Equipment, studies of new capabilities including Advanced Programs and Advanced Transportation Technology (such as Shuttle-C, Heavy Lift Launch Vehicle, and Human Exploration Initiative), Tether Satellite System, and the Orbital Maneuvering Vehicle (OMV).

* SPACE STATION -- requirements for FY 1991 and the following two years reflect the progress made in the development program. The detailed design phase of the program begins in FY 1991 and development hardware fabrication and testing activities must accelerate accordingly to support Critical Design Reviews in the following year. Also, key ground facilities required for testing, training, integration, and control must be completed in order to support the Station schedule. The request supports planned growth in the development effort to stay on track for assembly in orbit in March 1995.

In addition, the portion of the Research and Program Management (R&PM) budget managed by the Office of Space Flight totals $952.6 million and supports 10,361 full time equivalent positions. With Appropriation Realignment, the R&PM budget has taken on an even greater role as an integral part of the OSF program. The direct result of Appropriation Realignment on institutional requirements is that manpower, facilities, and services are more directly driven by program requirements. As program requirements increase, the demands on the institutional activities supported by R&PM also increase. This area of the budget also supports our travel requirements, which are considerable due to the wide geographic dispersion of our programs including the Space Station's international partnership. As Space Station's scope and pace increase, we require increases in both R&PM funding and the program's manpower ceiling. As efforts of Station contractors expand, our direction and oversight must also grow to ensure that R&D funds are spent wisely and efficiently. These activities are the basis upon which we are able to effectively conduct the critical Office of Space Flight Programs.

The NASA budget also includes several projects in the Construction of Facilities (CoF) request which are critical to the Space Station program. In 1991 we will begin construction of the Space Station Processing Facility at Kennedy Space Center (KSC), Florida, and the Neutral Bouyancy Laboratory at Johnson Space Center (JSC), Texas. We will also continue construction of the Space Station Control Center, and complete construction of the Space Station Training Facility at JSC. Full funding for these facilities is imperative to support plans to begin Space Station launch and

assembly operations in early 1995.

Shuttle Production and Operational Capability

The $1,302.0 million in Shuttle Production and Operational Capability is an investment in capabilities to effectively operate the fleet of Shuttle orbiters, and also provides for continued modification and improvement to the flight elements and ground facilities necessary to expand capabilities and safety margins. The total is distributed as follows: $213.6 million for orbiter operational capability, $822.9 million for propulsion systems, and $265.5 million for launch and mission support.

Orbiter Operational Capability

This $213.6 million funds capability investments in orbiter systems to support the mission model and operational requirements. Included are provisions for the logistics capability, inventory of spares, previously approved systems improvements, safety modifications, and engineering analyses and integration capabilities. The amount also provides for orbiter support activities such as the remote manipulator system, verification and validation of avionics interfaces, and the Convair 990 program for landing system analysis. Systems integration receives $11.1 million of the amount, while $52.4 million is earmarked for structural spares and $21.7 million for orbiter spares. Finally, $15 million is included for work on the Extended Duration Orbiter (EDO), in addition to the cryogenic kit being planned for development under a commercial arrangement with Rockwell International. The remaining $113.4 million is for orbiter modifications, improvements, and previously-mentioned support.

Propulsion Systems

The Space Shuttle Main Engine (SSME) program receives $430.9 million for the continued production of additional flight hardware and spare parts investments as well as continuation of development programs, including improvements to the current configuration and the alternate turbopump. Alternate turbopumps are being developed due to the limited operational life capability of the current high pressure turbopumps, which require overhaul after one or two flights. The new pumps will incorporate improved safety margins, life spans and reliability with a design requirement of 55 flights between overhauls. The product improvement program strives to improve safety and reduce costs, and has already done so in current production. It is anticipated that SSME modifications will likely increase its weight, but the resulting loss in performance will be overcome with inception of the Advanced Solid Rocket Motor (ASRM).

The Solid Rocket Booster (SRB) program receives $82.9 million. Primary focus of this funding is on continued evaluation and analysis of flight data to thoroughly assess the redesign. Modification of booster hardware will continue with the objective of obtaining the capability of at least 20 flight usage.

The Advanced Solid Rocket Motor (ASRM) program receives $309.1 million in fiscal year 1991, excluding facility construction costs. The amount supports the first full year of development as well as the continued buildup of plant equipment for the planned production facilities. The ASRM facility and equipment requirements are

funded through direct appropriation rather than the private financing proposed in the FY 1990 budget. The Request for Proposal (RFP) for the development phase of the ASRM was issued in August 1988. One contractor was selected for development with contract start anticipated during the second quarter of FY 1990. The development program is anticipated to extend for five years with the first flight of ASRM hardware in FY 1996. The scope of the development will include modification or acquisition of facilities, development and test of the new design, and production of verification units. The ASRM will increase reliability and safety in both the Solid Rocket Boosters and the total Shuttle system. It will also provide a projected 12,000 pounds of increased performance. Its development is comparable in scope and complexity to that of the SRM, while the technological base is greater than that at the start of the SRM project.

Launch and Mission Support

This activity directs $114.9 million to launch site equipment, to include activities improving the capability and processing efficiency in support of the flight rate. Included are the shuttle processing data management system, the OMRF upgrade, launch processing system equipment replacements, and the launch team training system.

The mission operations and support capability receives $150.6 million, providing for completing the replacement of host computers, automatic data processors, and other equipment in the mission control center. The Flight Analysis and Design System (FADS) system, dual-capability flight control room, improvements to weather prediction, information handling, mission control systems, and contingency landing sites are also covered in this account. Funding is also earmarked for mission support such as crew equipment — principally Extravehicular Mobility Units (EMU). Operations effectiveness and other support functions continue to support program-wide requirements, including flight safety, mission success, and flight rate capability.

Space Transportation Operations

This account provides launch services to NASA payloads using a mixed fleet approach of both the Shuttle and ELVs. Launch services are also provided on a reimbursable basis to the Department of Defense, other civil agencies, and certain commercial and international users. The Shuttle Program launch schedule is based on eight flights in FY 1990, ten in FY 1991, and eleven in FY 1992. The ELV launch schedule is a mix of launch systems in four performance classes: small, medium, intermediate, and large.

Flight Operations

The $815.6 million in this account is distributed to Shuttle mission support, integration and support functions. Mission support includes the flight operations activity at JSC for the ten missions to be flown in FY 1991 and initial efforts for FYs 1992 and 1993. These include maintenance and operation of all ground facilities necessary for flight preparation and execution, and instruction of flight and ground controllers. Also included are flight design activities and analyses and conduct of

planning necessary for each mission and maintenance of flight software. This budget will incur some support costs previously funded separately by the DOD, which plans to incrementally remove its requirements for secure operations support. Also included is sustaining engineering required to integrate all flight and ground elements and to assure systems safety and integrity, payload compatibility and interfaces, and crew operations and training. Support also continues for procedure and hardware modifications resulting from failure and criticality reviews, and sustaining engineering activities that ensure maintainability, reliability and anomaly resolution during operations. The amount also covers aircraft for proficiency, training and orbiter ferry requirements.

Flight Hardware

The $1,467.2 million in this category provides for procurement of External Tanks (ET), manufacture and refurbishment of Solid Rocket Booster (SRB) hardware and motors, and operational support to the orbiter including spares, ET disconnects, spare components and flight support for the main engines, and maintenance and refurbishment of flight crew equipment. Also, manufacture of flight support motors for static firing will continue in FY 1991, in order to monitor consistency of production characteristics, quality process, and design changes. Moreover, testing will be required to flight certify new sources of ammonium perchlorate for SRB propellant, and carbonized rayon used for nozzle parts.

Launch and Landing Operations

Manpower and support services necessary for processing launches from KSC are covered by the $606.6 million in this account. Funding also supports the manpower required for sustaining engineering, provisioning, logistics, launch processing system operation and maintenance, and maintenance and modification of all other Shuttle-related ground support equipment and facilities. Also included are funds for maintaining the Dryden Flight Research Facility, California, as a landing site.

Expendable Launch Vehicle (ELV) Services

The ELV budget request for FY 1991 of $ 229.2 million will continue to fund procurement of launch services from the private sector for civil government missions. Specifically, activity will continue on the Geotail (with Japan), Wind, and Polar missions under the competitively selected Medium ELV (MELV) launch services contract awarded in fiscal year 1990, as well as initiation of support for the U.S.-Canadian Radarsat mission. Under the MELV contract NASA will obtain three firm and twelve optional Delta II launch services to support NASA scientific requirements through the 1990's. The U.S.-German Roentgen Satellite (ROSAT) mission will be launched in 1990 on a USAF purchased Delta, while fiscal year 1991 funds will support launch of the Extreme Ultraviolet Explorer (EUVE) on a USAF procured Delta in 1991.

In 1990 NASA will issue a Request for Proposals (RFP) to competitively procure Small-class ELV (SELV) launch services from the private sector to support the NASA Small Explorer Satellite Program. The FY 1991 budget request provides initial funding for a series of seven firm and three optional SELV launch services, as well as

funding to continue support to the remaining three Scout vehicles planned for launch through 1993.

Unlike the SELV and MELV Programs which lend themselves to procurement of a series of firm and optional launch services, NASA's intermediate class launch requirements (payloads up to 30,000 lbs,) are being procured competitively on an individual basis. In November 1989 NASA signed a launch service contract to support the Mars Observer mission on a commercial Titan III vehicle which is supported by the fiscal year 1991 budget request. Intermediate class launch services for the Solar Heliospheric Observatory (SOHO) for the European Space Agency, and the Mobile Satellite (MSAT) will be initiated in FY 1990. The Combined Release and Radiation Effects Satellite (CRRES) launch on the first commercially produced General Dynamics Atlas I vehicle in 1990 will usher NASA into the new era of launch services.

NASA will continue to rely on the USAF for support to Large ELV-class requirements (payloads of 40,000 lbs.), since Titan IV's are currently unavailable commercially. The FY 1991 budget request continues mission integration activities to support both the CRAF and Cassini missions scheduled for launch on Titan IV's.

Space Transportation Capability Development

The $773.4 million in the Space Transportation Capability Development account is shared by a number of programs which cut across the OSF organization, and is distributed among eight NASA installations and Headquarters.

Spacelab

The Spacelab funding request for FY 1991 is $130.7 million. This funding level will support six Shuttle missions using Spacelab hardware in FY 1991. It will also support preparations for eight missions planned to be launched in FY 1992; and to initiate flight hardware processing for eight additional missions scheduled for FY 1993. In conjunction with supporting a substantial part of the Shuttle flight manifest during these years, the Spacelab funding will provide the necessary engineering and development activities for hardware recertification and return to flight status.

The Spacelab will return to flight in FY 1990 with the launch of two major scientific missions: Astro-1, an igloo pallet with an Instrument Pointing System (IPS) scheduled to be launched in the third quarter and a Space Life Sciences-1 (SLS) module mission scheduled for the fourth quarter. In FY 1990 we will be very active preparing and processing flight hardware for three international Spacelab module missions planned to be flown in FY 1991: the International Microgravity Laboratory (IML) mission, the Japanese/American (SL-J) mission, and the Italian/American cooperative Tethered Satellite System (TSS) mission. Spacelab hardware processing will also be in progress to support DoD payloads. One major DOD mission is the SDI Starlab module mission scheduled for launch in early FY 1992. Furthermore, Spacelab hardware preparation and processing in FY 1991 will be initiated to support major Shuttle missions in FY 1992 such as micro gravity materials processing type missions: United States Microgravity Laboratory-1 (USML) and United States Microgravity Payload-1 (USMP), Shuttle Radar Laboratory-1 (SRL), Atlas 2, SLS-2, and the German Spacelab

module mission SL-D2.

In addition to these missions, the Spacelab FY 1991 funding requirements will support the complete development of the modified Hitchhiker MPESS structure for experiments starting in 1992. The processing of many Hitchhiker and Get-Away-Specials (GAS) will occur during this timeframe. In December 1990 and June 1991, crossbay GAS bridge carriers will be launched with up to twelve GAS customer payloads per mission.

Spacelab hardware is used to support as many as eight missions a year with projections to continue this level of effort through the late 1990's. During this timeframe additional planned uses for Spacelab carrier systems to support Space Station Freedom as a precursor and test beds will be considered. Funds for the planning of the refurbishment and replacement of Spacelab carrier hardware is included in the FY 1991 request to meet the launch demands. We are currently conducting a Spacelab improvement study with the users which will be completed this year. The results of this study will be implemented in FYs 1991 and 1992.

Upper Stages

The Upper Stages budget request for FY 1991 is $91.3 million. The Upper Stages program encompasses procurements of Inertial Upper Stages (IUS), Transfer Orbit Stage (TOS), Centaurs, and a Solid Propulsion Integrity Program (SPIP). Upper stages boost payloads to orbits and trajectories not attainable by the Shuttle or ELVs alone. Requested funds will procure stages and provide technical monitoring and project management. IUS vehicles are procured through the DOD, and TOS vehicles are procured directly by MSFC. The TOS upper stage is being commercially developed and will be procured directly from the vendor. The Centaur is an integral element of the Titan IV/Centaur vehicle procured by the DOD and launched for NASA. MSFC manages the Solid Propulsion Integrity Program (SPIP), initiated in 1984, which establishes an engineering base for improving the success rate of U.S.-built solid stages, and is closely coordinated with the DOD to avoid duplication of efforts in this vital program.

In FY 1990, IUS production continues for the Tracking and Data Relay Satellites (TDRS) E and F, and the Ulysses mission. The Ulysses mission will use an IUS upper stage with a modified Payload Assist Module (PAM-S), a commercial upper stage. NASA launched one IUS mission (Galileo) in FY 1990 aboard the Space Shuttle. The TOS upper stages for the Advanced Communications Technology Satellite (ACTS) mission and the Mars Observer (MO) mission will continue production in FY 1990. The SPIP program will continue work on building the engineering base on solid propulsion stages in the areas of nozzles and bondlines, propellants, internal flows, and verification testing.

The FY 1991 funding request will support the IUS/Ulysses and IUS/TDRS-E launches, preparation of the IUS/TDRS-F for a FY 1993 launch, and initiation of production of an IUS vehicle for a TDRS-G launch in FY 1995. The TOS for the MO and ACTS missions will continue production for launch in FY 1992. Two Centaur vehicles will be procured for the CRAF and Cassini planetary missions to be launched in FYs 1995 and 1996, respectively. The production of the two Centaurs will be initiated by DOD

as part of the Titan IV/Centaur program. The SPIP will continue its investigation of materials, design tools, fabrication processes, and controls, will examine product evaluation and verification methods, and will improve engineering practices, procedures, and communications within the solid propellant community.

Engineering and Technical Base

The largest account under Capability Development is Engineering and Technical Base (ETB) which receives $218.5 million of the total. The ETB core varies from center to center due to programmatic and institutional differences. To supplement my earlier remarks about the accomplishments and plans for ETB, I would like to add comments about elements at the OSF centers. At Johnson Space Center (JSC), Texas, and White Sands Test Facility, New Mexico, ETB provides for five-day, one-shift operations in engineering and development laboratories. ETB provides center-wide computational services and Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) support for JSC and Marshall Space Flight Center (MSFC), Alabama. At Kennedy Space Center (KSC), Florida, the core level provides for technical laboratory support in such areas as robotic applications for launch vehicle umbilical and inspection systems, development of polymer coatings for launch structures, prototyping and testing equipment in support of ASRM and Shuttle-C, research in artificial intelligence applications, new fiber optics and digital electronics test and evaluation, and SRM&QA functions in direct support of the launch process. At MSFC, the core level provides for multiprogram support to technical laboratories and facilities, and to test facility operations. Starting in FY 1990, the ETB engineering support at MSFC will play an important role in ASRM development. At Stennis Space Center (SCC), Mississippi, ETB funding is utilized to maintain the supporting infrastructure necessary for current and future propulsion test programs, including SSME testing, ALS component testing, and ASRM testing. This infrastructure includes equipment, support personnel, and related special studies.

For FY 1991 the ETB budget provides capability to accomplish the following activities:

- Critical specific science and engineering support required for systems analysis and integration, propulsion, avionics, materials and processes, structures, and dynamics capabilities which are either not readily available or cannot be obtained within the civil service work force, especially at JSC and MSFC as the Space Station development continues and intensifies, and ASRM activity increases. In addition, the increasing flight rate places added demands on launch support.

- Enhanced support required for new programs and expanded technology associated with robotics laboratories, improved optical processor technologies, microwave integrated circuitry, artificial intelligence applications, and for new Space Station Freedom program needs and design concepts.

- Increased SRM&QA needs at all OSF centers.

Replacement of a significant backlog of aging and obsolete laboratory equipment which continues to deteriorate as equipment requirements are deferred due to limited funding.

Payload Operations and Support Equipment

Payload Operations funding in the amount of $94.2 million is required for continued payload services to currently scheduled launches. Major NASA payloads to receive support include Hubble Space Telescope (HST), Tracking and Data Relay Satellite (TDRS), Space Radar Laboratory (SRL), Space Life Science Laboratory (SLS), Upper Atmospheric Research Satellite (UARS), and Gamma Ray Observatory (GRO). Funding is also required to initiate technical integration and operations activity to assure compatibility between Shuttle capabilities and Space Station transportation requirements. A docking system is being developed as part of this activity.

Payload Support Equipment funds of $28.3 million reflect the requirement to modify and upgrade selected payload integration facilities for safer and more efficient operations. Also included are orbiter/payload interface hardware for groups of payloads, cargo bay cabling, modified aft flight deck panels, and associated displays and controls.

Advanced Programs

The Advanced Program Development request is $53.2 million in FY 1991. Identification of future space transportation and related initiatives is the focus of this program area which provides the technical as well as the programmatic data for future national decisions on space transportation alternatives. Definition study and supporting advanced development activities will continue in FY 1991 with primary emphasis on advanced space transportation systems, advanced operations support systems, and satellite servicing systems. Other activities include tether applications and orbital debris studies.

Concept definition (Phase A-prime) studies of the Assured Crew Return Vehicle (ACRV) will be conducted in FY 1990 with the follow-on systems definitions (Phase B) planned in FY 1991. The FY 1991 effort will include preliminary design of space-based vehicle concepts for three mission areas: crew illness or injury, Space Station Freedom accidents, and Space Shuttle unavailability.

The Shuttle-C definition effort is focused on a near-term heavy lift capability utilizing Shuttle elements while replacing the Orbiter with a cargo carrier. The preliminary design for the basic Shuttle-C concept will be completed during FY 1990. Heavy lift vehicle studies will be initiated in FY 1991 to build upon the Shuttle-C studies.

Concepts for a high performance upper stage, the Space Transfer Vehicle (STV), will continue to be studied during FY 1990. Originally conceived as a near-term solution for unmanned planetary and geosynchronous mission requirements, the studies have also considered evolutionary concepts to meet space transfer needs for human exploration.

Improved cost effectiveness, mission success, and flight safety are the objectives of operations support systems studies and development. Two current projects are being transitioned into flight operations process for FY 1990. One of these enables the efficient use of distributed data processing systems for mission support and the other utilizes expert system technology to automate the task of error message reporting.

We have been involved with the DOD and the Department of Transportation on a research plan focused on assessing the orbital debris environment, developing design criteria for the Space Station Freedom, minimizing debris, determining spacecraft survivability, and using results of this research to formulate future regulatory options. During FYs 1990 and 1991, studies will continue to assess the orbital debris environment and to develop techniques to protect in-space assets.

NASA completed a pre-Phase B study of the Satellite Servicer System (SSS) Flight Demonstration. This study co-funded by DOD/SDI was focused on using the OMV and elements of the Flight Telerobotic Servicer (FTS) to demonstrate autonomous rendezvous and docking, and supervised autonomous orbital replacement unit exchange as well as fluid resupply. Future development on an operational SSS will enable NASA or DOD to service satellites in orbits not reachable by the Shuttle as well as safely undertake hazardous servicing missions. Utilizing the OMV and elements of the FTS will enable both NASA and DOD to develop a cost effective servicing infrastructure. A jointly funded and jointly managed Phase B effort will be initiated in fiscal year 1990.

This year we also completed the engineering design and fabrication of three flight experiments related to satellite servicing. The Optical Communications through the Window (OCTW) experiment will provide payload bay users with a stand-alone communications link between the Shuttle payload bay and the crew cabin. The Voice Controlled TV (VCTV) will improve STS crew performance by providing voice control for the Shuttle bay TV cameras. Both of these flight experiments are manifested to fly in October 1990. The Small Expendable Deployer System (SEDS) will demonstrate the ability to routinely de-orbit material from a space station or place instruments deep into the upper atmosphere using an inexpensive expendable tether system. The SEDS concept will be demonstrated as a secondary payload on an Air Force Delta II rocket in mid 1991.

Advanced Transportation Technology

Our objective for advanced transportation technology is to define concepts and demonstrate initial launch vehicle technologies which will support the heavy lift launch vehicle requirements of the Human Exploration Initiative. Systems analysis and concept definition of wide-body and cryo tanker heavy lift launch vehicles will be conducted in conjunction with Shuttle-C, the Advanced Launch System (ALS), and other potential vehicle concepts.

NASA is requesting $40 million to augment the ALS Space Transportation Main Engine (STME) systems definition and advanced development efforts in FY 1991. The ALS program has been restructured to accommodate a reduction in DOD FY 1990 funding. This restructuring includes a significant reduction in scope for the DOD-managed vehicle studies and a re-focusing of priorities toward propulsion

technology. NASA will continue the management responsibility for the Advanced Development Program (ADP) and liquid engine systems definition and advanced development work, and will assure that critical tasks are completed to support future decisions on an STME program. The augmentation is necessary to assure technology maturation to support the development of the next generation, highly reliable yet low cost engine which could have application for the Human Exploration Initiative. The Component Test Facility at Stennis Space Center is under construction and supports the engine development schedule.

We are also requesting $10 million in FY 1991 to perform design studies which will address the specific requirements for a tanker to move large quantities of cryogenic propellants to orbit, and for a large volume cargo carrier. These studies will consider both Shuttle derivatives and the ALS vehicle concepts.

Also in FY 1991, $3.9 million has been requested to address unique civil requirements not covered in the ALS baseline program. The ALS civil studies include definitin of civil mission requirements, transportation infrastructure analysis (ETO vehicle and space transfer vehicle trades), space transfer vehicle concepts, and Space Shuttle/ALS booster commonality analysis.

Tethered Satellite System (TSS)

The first TSS mission is scheduled in September 1991. The final integration and launch preparation for this mission, as well as post flight data reduction, hardware disassembly and system update will require a funding level of $17.9 million in FY 1991. During the FY 1990 activities, the TSS will undergo final assembly, system level qualification testing and the initiation of the hardware integration process at KSC. Delivery of flight hardware to KSC is scheduled for early summer 1990.

The TSS is a cooperative US/Italian development of a reuseable Shuttle based space facility. The first mission will demonstrate the capabilities of the system and conduct electrodynamic investigations. The TSS will be deployed 20km (12 miles) above the Orbiter on a conductive tether. Electricity will be generated as the connected Orbiter and Satellite pass through the magnetic field lines of the earth. Both the satellite and the deployer, which is attached to the Orbiter bay, will be instrumented to study the generation process. Italy will develop the satellite and provide integration of all scientific instruments. NASA will provide the TSS deployer, perform system-level engineering and integration, and deploy the spacecraft from the Shuttle. An Italian payload specialist will fly on the first TSS mission.

The TSS concept can be used to study near earth atmosphere in regions unreachable by conventional satellites, to provide applications of practical, as well as, scientific value to the Space Station, and as a tool in planetary exploration. We are currently investigating the potential of a second mission to conduct aerothermodynamic investigations in the 130km orbital region.

Orbital Maneuvering Vehicle (OMV)

The OMV request for FY 1991 is $85.4 million which is substantially less than the FY

1991 estimate submitted in FY 1990 Budget ($175.4 million). This reduction is a result of restructure of the OMV program and rescope of the design which were undertaken because of cost-growth threats, and reassessment of vehicle requirements.

The restructured OMV design will be capable of performing orbital operations up to 275 nautical miles beyond the practical operational range of the Shuttle. Using remote man-in-the-loop control for proximity operations, the OMV will deliver, retrieve, and reboost a broad spectrum of satellites. Specifically, the OMV will reboost the Hubble Space Telescope (HST) up to approximately 180 nautical miles above the Shuttle orbit and the Advanced X-Ray Astronomical Facility (AXAF) 140 nautical miles above the Shuttle orbit. In addition, it will reboost a variety of satellites to their original operating orbits, retrieve them for repair at the Shuttle, and return them to their operating orbits. In addition, the restructured design will accommodate system enhancements in propulsion, power generation, navigation, and payload support services which would be added as mission kits as future requirements are defined.

The FY 1991 funds will finalize the OMV design and initiate fabrication and testing. The OMV development schedule is paced to support a demonstration flight in April 1995. The program Critical Design Review is scheduled for April 1991.

Space Station

In presenting the FY 1991 Space Station Freedom budget request, there are four principal points about the program which I wish to emphasize:

First, our objectives for Space Station Freedom have not changed. For our science program, Freedom offers a laboratory for research in many scientific disciplines and a platform for instruments to look out at the universe as well as back toward the Earth. For technology development, Freedom will be a unique national facility - a testbed for evaluating technologies, procedures, and design approaches for potential application in future space systems. For our exploration program, Freedom's manned base represents the establishment of a permanently manned oupost in space and a stepping stone for the missions of the future.

Second, our progress to date on the Space Station has been substantial. The First Element Launch milestone is one year closer now than it was at our last budget hearing before this Subcommittee, and our design and development effort is moving forward accordingly on all fronts. The Space Station is developing hardware and necessary infrastructure. Many of our important accomplishments to date involve tangible hardware items, including hundreds of breadboards, proof-of-concept development items, testbeds, test articles, mock-ups for human factor analysis, and technology demonstration hardware.

Third, some program adjustments have been required in the last year, but the basic integrity of the Space Station program is intact. The reduced funding for FY 1990 and the resulting need to minimize near-term program costs, technical risks, and schedule risks forced some changes in program plans, primarily involving the schedule for outyear assembly milestones and addition of planned capabilities.

Despite these recent adjustments, however, the fundamental objectives of the Space Station program are unchanged, and the planned capabilities of the Space Station are maintained.

Finally, as you well know, full funding for FY 1991-1993 is necessary if we are to avoid additional disruptions in the Space Station development effort. The stability that is required can only be provided by multiyear funding. This Committee has understood this reality and demonstrated its strong support for the program by approving the Space Station's existing multiyear authorization. Renewal of this multiyear authorization and initiation of a multiyear appropriation are essential if we are to complete the baseline Space Station before the start of the twenty-first century.

There are two significant differences between the FY 1991 budget request and previous requests. First, beginning with FY 1991 the Space Station budget no longer contains funding for the Polar Platform project, which has been transferred to the Office of Space Science and Applications as part of the Earth Observing System (EOS) program. Second, for the first time the request contains funding for Human Exploration Initiative study activities in the Advanced Programs budget line. These activities will examine Space Station capabilities and technologies that may be required to support manned missions to the Moon and Mars.

Work Package 1

In FY 1991, the Work Package 1 team will be heavily involved in the final design of its distributed systems in preparation for their CDR in early FY 1992. The preliminary design of the U.S. laboratory module will be completed, its PDR will be conducted, and final design activities will begin in preparation for a CDR in FY 1992. Engineering manpower for design and analysis activities will increase to support the FY 1992 PDRs for the habitation module and logistics carriers. Other key activities include procurement of hardware for development and qualification testing of the Environmental Control and Life Support System (ECLSS), and testing of the integrated ECLSS subsystems in a simulated module. Structural test articles for the nodes and cupolas will be fabricated and used to conduct structural loads and environmental tests.

Supporting development activities at Marshall Space Flight Center include providing test facilities and related support (such as meteoroid/debris protection testing, seal development, berthing mechanism testing, module pressure/structural testing, and environmental testing) for prime contractor development efforts. Also included are ECLSS systems analyses, development testing and simulations, and materials properties assessments, including metallurgical support and lubricant evaluation. Other planned supporting development activities include systems engineering and integration, as well as implementation of a comprehensive technical and management information system.

Work Package 2

The Work Package 2 team will focus on the CDR for the Data Management System in support of the first delivery of a data management system kit in FY 1991.

Engineering development units for the assembly work platform, the mobile transporter, the astronaut positioning system, the communications and tracking system, the hyberbaric hatch, and the thermal control system will be delivered. Testing will be conducted to support the program CDR the following year. Engineering design and evaluation of the guidance, navigation, and control system, mechanical systems, and other systems will continue.

Supporting development activities will continue in preparation for the CDR. At Johnson Space Center, supporting development provides for all the test and facility manpower required for independent analytical support to assess system design viability, test article outfitting, and testbed operation. For example, supporting development activities for the truss assembly will include integrated loads and dynamics analysis, structural testing, materials usage assessment, structural assembly and berthing verification, and hypervelocity impact testing. The manpower, laboratories, computational capabilities, and hardware required for these analytical tasks will be supplied by supporting development contractors.

Work Package 3

After the Polar Platform is transferred out of the Space Station program, the primary item remaining in this work package is the Attached Payloads Accommodation Equipment (APAE). The preliminary design of the APAE will be completed, the PDR will be conducted, and detailed engineering design and analytic work will begin. Goddard Space Flight Center's supporting development activities include defining APAE common equipment, providing data support services and technical discipline support to structural/thermal analysis, defining contamination and monitoring requirements, and performing risk assessments.

Flight Telerobotic Servicer (FTS)

The major FTS activity next year will be integration and launch of the first development test flight on the Shuttle. The primary objective of this test flight will be to evaluate the FTS design and man-machine interfaces through the use of a manipulator system, a preliminary workstation, and software. DTF-1 hardware and software testing will receive particular emphasis, and astronaut training on the DTF-1 training system and simulator will begin after completion of checkout. PDR's for the second development test flight and the FTS itself will also take place, and FTS components will undergo continued development and test.

Supporting development activities include development of equipment for crew training, flight operations support, and integrated flight simulations. Efforts will continue on applications procedure development and studies supporting potential enhancements.

Work Package 4

The Work Package 4 team will continue work on the development and qualification of the solar cells and blankets. Energy storage assembly qualification cells will be fabricated and tested. Detailed design and testing of module items such as electrical

equipment assemblies and beta gimbals will continue. Power management and distribution (PMAD) system components and orbital replacement units will undergo detailed design during FY 1991. End-to-end testing of PMAD components will be completed in late FY 1991, and hardware will be delivered to Lewis Research Center in preparation for the electrical system integrated test planned the following year.

Supporting development activities include independent verification of the prime contractor systems engineering and integration efforts. Also included is the provision of a facility to conduct electrical integrated testing, "fleet leader" battery testing, and system validation of the photovoltaics module.

Operations/Utilization Capability Development

JSC will complete requirements definition and design of the Space Station Training Facility and the Space Station Control Center. Construction of these facilities will begin, with the objective of having them ready in 1993. Related hardware and software acquisition activities will also begin. Software development activities of the operations planning and analysis system will continue at an increased pace.

MSFC will define design and operations requirements for the Payload Operations Integration Center to provide an initial operational capability in 1995. A request for proposals will be released for systems development and procurement of the Payload Training Center, which is scheduled to have an initial operational capability in 1995.

KSC will begin significant equipment purchases, and will increase activity in planning, scheduling, systems software development, and manpower buildup for the Test, Control, and Monitor System (TCMS) and the Space Station Processing Facility. The TCMS PDR and the logistics information system CDR will be completed. Requirements for the Space Station Hazardous Processing Facility will be baselined.

Level II will refine facility requirements for Space Station operations and utilization in the Functional Control Documents, which will provide a basis for coordinating operations and utilization planning activities of the NASA centers and international partners.

Management and Integration

Management and integration activities will continue to focus on engineering integration, expansion of the Software Support Environment (SSE), and operation of the Technical and Management Information System (TMIS). The Space Station Engineering and Integration Contractor (SSEIC) will assist NASA in a broad range of activities required to prepare for completion of the program PDR in December 1990 and the CDR in FY 1992. These system engineering tasks include top-level stage definition for key stages of assembly, analysis of stage performance and assessments of the design against the requirements. The system integration tasks include integrated scheduling and development of verification plans, engineering data bases, and interface control documentation. Program plans will be developed for system safety and quality assurance, launch package integration, on-orbit assembly and

checkout, and integration with the Space Shuttle. The SSEIC will have an increased role at the field centers based on the relocation of the systems and element integration responsibilities to JSC and MSFC. For example, the SSEIC will support the Level II offices at these centers in preparing and maintaining Interface Control Documents, Architecture Control Documents, and Baseline Configuration Documents.

The SSE operational capabilities will be expanded by increasing and improving existing capabilities in the Software Support Environment Development Facility and the Software Development Facilities at contractor sites. In FY 1991, the Software Production Facilities at the field sites will be supported and additional facilities put in place as required. Incremental delivery of TMIS products will continue. Efforts will continue toward completing electronic bridges needed to link together contractors, NASA centers, and domestic and international users. Technical and resource information management, tracking systems, and databases will continue to be developed, with emphasis on those elements required to support the program PDR and CDR.

Advanced Programs

In FY 1991, Advanced Development and Advanced System Studies activities will ensure that the baseline Space Station will have the capability to add new functions, expand planned resources, and avoid obsolescence through technology upgrades. Advanced Development tasks will continue to emphasize advanced automation, robotics applications, and technology development to improve flight and ground system productivity and reduce long-term operations costs. Activities planned include: demonstration of knowledge-based automated subsystem control for flight and ground systems applications and cost effective software test/integration; and, demonstration of FTS operator/robot shared control in support of both the DTF-1 flight experiment, and the demonstration of large robot control from a remote site. Advanced System Studies will continue definition of an evolution reference configuration, including analyses to identify baseline configuration impacts and operational compatibilities associated with the more capable Station. Continued analyses are planned of the Station's distributed systems to define and document critical evolution design requirements before hardware construction.

The Human Exploration Initiative will likely evolve Space Station Freedom beyond its baseline configuration capabilities. Supporting potential transportation requirements may necessitate additional structure, power, servicing, and other capabilities. $20 million of the Advanced Programs request is for exploration technology to begin to study systems-level enhancements, and to begin the advanced development and preliminary design of the following crucial systems: Space Station-based EVA and high pressure suits; solar dynamic power; expanded hybrid power distribution and management system; and advanced propulsion. A special study on concepts of advanced automation and robotics for potential space transfer vehicle assembly, checkout, and servicing will be initiated to determine an appropriate mix of automation and EVA that may be needed to support potential mission operations. The focus of these efforts will be to ensure that the essential hooks and scars to support HEI are identified and incorporated into the baseline program. Planning for these activities is being closely coordinated with the Exploration Technology

program.

Space Station Operations

FY 1991 is the first year for funding operations. The early operations activity includes the establishment of a logistics system and spare parts for the flight systems. The FY 1991 funding in this area will allow for the procurement of long-lead materials required to begin establishing the spares inventory. These procurements need to be initiated in FY 1991 to ensure that spares are available to support launch site processing as well as on-orbit operations for early assembly flights. As the Space Station Program moves into its operational phase, the operations budget will provide for sustaining engineering, logistics, crew training, hardware processing, and other operational costs.

PROGRAM CONCERNS

Space Transportation

Our space transportation program has several major near-term concerns to which I wish to direct the Committee's attention. First among these is hardware obsolescence. The first Space Shuttle was delivered over ten years ago and was the product of 1970s design and construction. Our planning calls for operation of these orbiters for at least another twenty years, and perhaps more. In order to assure the Shuttle remains safe, serviceable, and effective in meeting evolving transportation requirements, it is imperative that we plan for the replacement of systems with current designs and technology. This has been an ongoing process with the development of such items as improved General Purpose Computers, solid state star trackers, and enhanced multiplexer-demultiplexers. Eventually, other Shuttle systems must be upgraded to modern flight standards. Examples are glass cockpit displays and the Global Positioning System Navigation System. Such improvements require years of advance development.

I also wish to reiterate our needs in the Research and Program Management account. Appropriation realignment made the R&PM budget significant to the programs in ways which are simple, but vital. For example, printing flight documentation is funded in R&PM, although it is a pre-flight requirement. Utility bills are paid in R&PM, yet without electricity, heat, and air conditioning, we cannot function. Finally, all civil servants are paid in R&PM funds, as is the cost of the travel they perform in support of our programs. Our FY 1991 request is austere, but supports these programs.

Other program challenges and concerns of which the committee should be aware are as follows:

* Meeting the increasing flight rate while maintaining high safety levels during orbiter processing.

* Major fleet modifications and implementations, such as drag chute installation and redundant nose wheel steering, will require orbiter down time and challenge our ability to meet the planning manifest.

* Maintaining our capability to build additional orbiters. Final delivery of components to Endeavour (OV-105) will mean vendors will have smaller business bases and either charge greater costs or layoff technical personnel. Loss of this capability is a concern to our logistics program and affects future decisions on orbiter production.

* As experienced engineers transfer and retire, significant corporate knowledge is lost. Attracting and retaining good people is a high priority.

* Due to age, service life uncertainties, and structural concerns, we must begin planning for procurement of replacement Shuttle Training Aircraft (STA). The current fleet leader has a predicted end-of-service life of 1994.

Space Station Freedom

The following are our primary challenges and concerns regarding the Space Station Freedom program:

* Implementing our plan to begin assembly in early 1995 and complete the Space Station by mid-1999 depends on maintaining an adequate and stable funding profile. At the very least, inadequate funding would disrupt the development effort, delay our schedule, and increase program costs.

* The program will conduct more than 80 subsystem PDRs in 1990 leading up to system-level PDR in December 1990. The intensity and manpower requirements across the program will be focused on this accomplishment.

* The program will define and baseline element-to-element interfaces and element-to-distributed system interfaces. Baseline Configuration Documents will define hardware locations within modules and on the truss structure. Functional Control Documents will define the flight-to-ground system architecture. Architecture Control Documents that were baselined last fall will continue to be updated as necessary to reflect approved changes in the upcoming PDRs.

* Weight and power controls were baselined at the work package level last fall. Continued assessment of these controls and baseline control of crew time and volume will occur this year.

* Debris protection criteria will be baselined and reflected in the PDR this year. In addition, a debris protection plan will be developed that minimizes the likelihood of impact damage.

* We will continue to assess operations costs to refine our earlier estimates. Life cycle cost control depends on understanding and controlling operations costs.

CONCLUSION

We often draw analogous comparisons between the space program and previous breakthroughs in transportation which have opened new vistas, economic opportunity, and cultural growth. Space transportation has occupied only a brief moment in human history, and has quickly transformed our lives in ways we could never have anticipated. As our capabilities mature and our opportunities expand, even the most optimistic visionaries likely can not forecast the achievements and wonders which lie ahead. As the next step toward this bright future, we are eager to work with you, Mr. Chairman, and the Members of the Committee, toward the expedient implementation of this budget

I will be pleased to respond to any questions you may have concerning this budget and these important issues.

National Aeronautics and Space Administration

Hold for Release Until Presented by Witness

February 21, 1990

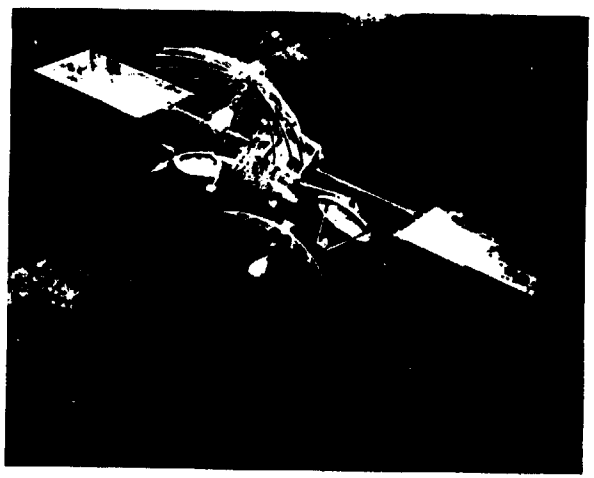
Subcommittee on Space Science and Applications

Committee on Science, Space and Technology

House of Representatives

Statement by:

Charles T. Force
Associate Administrator for Space Operations



101st Congress

HOLD FOR RELEASE
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BY WITNESS

STATEMENT OF
CHARLES T. FORCE
ASSOCIATE ADMINISTRATOR
FOR SPACE OPERATIONS
National Aeronautics and Space Administration
before the
Subcommittee on Space Science and Applications
Committee on Science, Space and Technology

House of Representatives

Mr. Chairman and Distinguished Members of the Committee: Thank you for this opportunity to present that portion of the President's Fiscal Year 1991 budget request corresponding to the Office of Space Operations responsibilities. NASA's Administrator, Admiral Richard H. Truly, in his testimony earlier this month mentioned highlights of NASA's recent accomplishments and provided a compelling statement of how NASA's mission significantly contributes toward building a better America. We are proud to be a participant in these achievements and look forward to the important and challenging endeavors of the future.

INTRODUCTION

The Office of Space Operations (OSO) responsibilities include an array of functions *critical* to this nation's space programs. They are:

- Spacecraft operations and control centers;
- Ground and space communications;
- Data acquisition and processing;
- Flight dynamics and trajectory analyses;
- Spacecraft tracking; and,
- Applied research and development of new technology.

When viewed as a unit, these activities are one leg of an interdependent triad that is ***absolutely essential*** to this nation's space programs. OSO functions, while often less visible, are no less vital than the other triad legs: the payloads and the space transportation systems that carry them to their destinations. Mission success is possible only when ***all triad elements*** meet their performance requirements.

SOME ACCOMPLISHMENT HIGHLIGHTS

The epic encounter with the planet Neptune in August 1989 illustrates the triad concept. With the successful ***launch*** of Voyager 2 in August 1977, that leg of the triad was achieved. Voyager 2's triumphs included flybys of Jupiter, Saturn, Uranus, and finally Neptune in its fourth planetary encounter. Voyager 2 now continues its incredible journey into interstellar space -- successfully completing the ***spacecraft*** leg. Throughout these 12 years, the payload operations, control, tracking, communications, data acquisition, and relay systems fulfilled the ***remaining triad*** requirement.

By far, the most challenging Voyager 2 task for the Deep Space Network (DSN) communications team was that of obtaining the five million data bits required to construct each of the 9,000 Neptune images. When Voyager 2 encountered Neptune, it was half again as far from Earth as in January 1986 when it passed Uranus. As a result, the power of the signal at Earth was diminished by 50 percent. To receive television images from Neptune, at the record distance of 4.4 billion kilometers, augmentations to the Deep Space Network (DSN) were required. By combining twenty-seven 25-meter antennas of the National Science Foundation's Very Large Array in New Mexico with the DSN's 70- and 34- meter antennas at Goldstone, sufficient signal energy was received from Voyager 2. Similar augmentations were made at Canberra. The communications team succeeded in capturing and processing data with the weakest signal level received in history. The return on these investments was the once-in-a-lifetime image set from Neptune.

In a similar manner, the OSO functions were a vital part of the other numerous 1989 NASA achievements in space -- most notably the series of Shuttle flights and the initial phases of Magellan and Galileo missions.

Another significant 1989 milestone, I would like to highlight, was achieving operational status of the Tracking and Data Relay Satellite System (TDRSS) in the Space Network.

In the pre-TDRSS era, over 30 sophisticated ground stations were used in complex, worldwide networks to track and communicate with Earth-orbiting spacecraft. Even with extensive ground-based networks, communications were limited to increments of time corresponding to the coverage from each ground station. In total, these ***noncontinuous*** increments provided coverage for only ***15 percent*** of each Earth orbit.

Today the three Tracking and Data Relay Satellite (TDRS) constellation, linked to the White Sands Ground Station in New Mexico, provides ***continuous*** coverage with a full range of communication capabilities for over ***85 percent*** of each spacecraft orbit. Especially important is the cost-effective increase in data volume accommodated. This giant step forward makes possible corresponding increases in data returns from and efficiency of spacecraft operations.

Without the support of this Committee, these and the other NASA accomplishments would not have been possible. We are mindful of this fact and express our sincere appreciation.

UNIQUE ASPECTS

Before presenting the FY 1991 budget details, I will describe some unique aspects of the Space Operations responsibilities that help to place them in a broader context. Specifically, they are the continuous, the multi-mission, and the technology aspects of the Space Operations role. We are aware of these in our daily activities and as we prepare for the future.

First is the continuous nature of the Space Operations functions. For example, our networks do not start or end with a given launch or even a spacecraft mission. Again, Voyager 2 is a good example. Its 12-year mission was dependent upon the DSN. Network operations continue because Magellan, Galileo, and more than a dozen other spacecraft now in space require the DSN. Soon, the Ulysses and Mars Observer spacecraft will join this group. Successful completion of all these missions is not possible without the Deep Space Network.

In a similar manner, each Shuttle mission, the Cosmic Background Explorer, the Earth Radiation Budget Satellite, the Landsat 4 and 5 and other spacecraft require the TDRSS Space Network. In the near future, the Hubble Space Telescope, the Gamma Ray Observatory, the Upper Atmospheric Research Satellite and others will be added to this impressive list of satellites dependent on TDRSS to accomplish their missions.

The ultimate return on the investment in these missions is directly linked to the capability and reliability of the communications networks. Within the many ever-present constraints, we must do all that is reasonably possible to assure that this critical link is adequately staffed, operated, and maintained. Otherwise, ***significant portions*** of this nation's total ***investment*** in space are at risk.

OSO exists as a separate program office to facilitate sharing of vital and sophisticated resources required by all space missions. This multi-mission approach dramatically reduces operational costs. The expense of accommodating new requirements is far less than if new, special purpose facilities were dedicated to each new mission. Conversely, only a small

cost reduction may be realized with the completion of a single mission because many other programs remain dependent on the basic infrastructure. On the other hand, finding ways to reduce multi-mission operations costs would have a broad impact.

All spacecraft built today incorporate the latest advances in technology when practical. But, the rate of technological change varies dramatically from one technical discipline to another. Few, if any, match the advances made in communications, control, and data systems. For example, from Explorer I to Voyager 2, the telecommunications capability increased by ***18 orders of magnitude***. These areas of rapidly advancing technology are in the mainstream of Space Operations activities; thus, a substantial effort must be devoted to upgrading our capabilities. Capitalizing on these advances accounts for our ability to achieve ever so much more without corresponding budget increases. The Space Operations infrastructure must keep pace with the advancing technology in order to ***cost effectively*** fulfill its vital role in achieving this nation's goals in space.

The NASA space program requirements in this decade and beyond demand the increased efficiencies, reliability, and capabilities that are available through the use of new technologies. These must be integrated into the existing networks efficiently and without interruptions to the on-going operations.

We look forward to meeting these challenges by providing the dynamic Space Operations infrastructure needed to cost-effectively satisfy the requirements of this nation's space programs.

FY 1991 BUDGET REQUEST

OVERVIEW

The FY 1991 budget request for Space Operations is $889 million.

This amount is less than six percent of the total NASA request, compared to an average of greater than nine percent of appropriations over the last 25 years. In FY 1991, we must meet the increasing activity levels of the flight programs, as well as the initial study and development activities for such programs as the Earth Observing System and Space Station Freedom. It is a special challenge to meet these requirements given the constraints of the FY 1991 budget request.

Of the total funding requested, 60 percent is required to operate and maintain the in-place Space Operations facilities. Nearly all of the remaining 40 percent provides for replenishment of Space Network assets and development of ground systems necessary to meet requirements of the NASA space programs planned through FY 1995.

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The FY 1991 Space Operations budget request contains no funds for the loan payment to the Federal Finance Bank (FFB) because the Administration is requesting authority to repay all outstanding debt to the FFB for TDRSS.

SPACE NETWORK PROGRAM

The FY 1991 budget request for the Space Network Program is $331 million.

The Space Network provides tracking and communications for Earth-orbital and suborbital missions. Key elements of the network are: the TDRS in orbit and under production; the White Sands Ground Terminal; the Second TDRSS Ground Terminal; and the Goddard Space Flight Center's Network Control Center (NCC) and Flight Dynamics Facility (FDF).

In 1989, the Space Network achieved the major milestone of operational status with TDRS-1, -3, and -4 in orbit. Missions using TDRSS have realized better than 98 percent of their requirements for science data over the past year.

During the STS-32 mission, TDRS-3 suffered a failure in a power circuit affecting K-band service from one of its two single access antennas. The K-band is operable, but its polarization switch is "locked" in the wrong position to support users. We believe the other TDRS-3 services remain operational. Further analyses are required to determine recovery options and appropriate actions.

The Second TDRSS Ground Terminal (STGT) is progressing on schedule. This new facility at White Sands will eliminate a critical single point of failure, and add the necessary capability to operate more than two TDRS in the future. The building has been accepted, and preliminary design reviews were completed with General Electric, the technical systems contractor. In 1991 we will be past the funding peak, and will begin testing the first string of equipment. After the STGT is operational, the existing ground station will be refurbished with identical equipment for economy of operation.

In 1990, TDRS-5 will be completed and prepared for a January 1991 launch; assembly of TDRS-6 will also be completed. Critical design reviews of TDRS-7 are finished, and it is being assembled for a 1992 delivery. Analyses show a 50 percent probability of need for TDRS-8 before the first of the next generation spacecraft can be available in late 1997. This is not an acceptable risk. Thus, to maintain the TDRSS network, an eighth spacecraft of the present design must be obtained. This budget request includes funding for exercising the TDRS-8 contract option.

NASA's Flight Assignment Board recommended that the launches of TDRS-7 and TDRS-8 remain as scheduled on the Shuttle. The cost impact of switching to Expendable Launch Vehicles (ELV's) would be over $200 million. An added risk to successful launch and deployment also exists by changing from a well-understood launch environment and experienced launch crews.

The design of a series of spacecraft necessarily changes with time. Few components in this rapidly changing technological age remain in production for decades. Thus, when TDRS-7 was started, many components used in the original design were obsolete and no longer available. Incorporating new components is costly, entailing redesign, testing, and recertification. As time goes on, a design which was initially optimized and balanced becomes a hodgepodge of changes. At some point it is appropriate, both economically and technically, to start over with the next generation of spacecraft. In our view, the TDRS program has reached that point.

Because of the possibility that near-term expenditures might be lower, we have considered purchasing a ninth TDRS in the present series and slipping the follow-on program. Such an approach does not appear prudent. Envisioning the possible need for an additional spacecraft, the contract for TDRS-7 included some long-lead parts for a TDRS-8, but no parts for any more spacecraft. Because many components are either obsolete or not available, it is already too late for a TDRS-9 to be identical with TDRS-8. If we were to extend the present contract to include TDRS-9, the most economical approach would be to initiate procurement of additional parts as soon as possible, and construct the spacecraft at the end of the TDRS-8 build. This would require increased 1991 funding. Delaying the start of TDRS-9 would give us another dilemma: the longer we wait, the more the TDRS-9 design would change. Further, little of the investment in design modifications would be of value to the follow-on program.

Continuing modification of the design of a 1977 vintage spacecraft, and purchasing the spacecraft one at a time without competition, is expensive. We believe a competitively designed and procured follow-on series, incorporating technology of the 1990's, will provide superior end items at a lower cost to the taxpayer.

Our second generation spacecraft is Advanced TDRSS, or ATDRSS. In looking at comparable milestones, ATDRSS follows TDRSS by about 16 years. Requested FY 1991 funding is needed to complete the Phase B competitive design studies. Funding for construction will start when a new contract is awarded in mid-1993. This contract will be a competitive selection, and deliver spacecraft for TDRS-9 through TDRS-17. It will provide for evolution of the telecommunications payload, the spacecraft buss, and delivery to orbit, as economics, technology or requirements make appropriate. In accordance with a recommendation of the Flight

Assignment Board, the contractors are designing for Expendable Launch Vehicle (ELV) transportation and considering delivery on orbit. We plan to ensure the essential continuation of the Space Network through the year 2012.

In the mid-1990's, an additional TDRS spacecraft will need to be placed in orbit to meet a doubling in the projected number of users. At that time the TDRS constellation will consist of four spacecraft in orbit, compared with three today. We will begin operating two TDRS's over the Atlantic and two over the Pacific. In-orbit spare capacity will then consist of essentially an extra spacecraft antenna at each location, rather than a centrally located spare spacecraft as configured today.

The recent TDRS-3 anomaly serves to emphasize the need to adequately provide resources to ensure viability of Space Network operations.

GROUND NETWORKS PROGRAM

The Space Operations Budget request for FY 1991 includes $268 million for the Ground Networks Program. Funding for this program provides for operation, maintenance, and engineering of the worldwide tracking facilities. Also included is funding to upgrade the facilities to meet requirements for approved new missions.

The Ground Networks provide Earth-based tracking and data acquisition services to NASA's aeronautics, science, and applications missions. There are three major elements of this program: the Deep Space Network (DSN); the Spaceflight Tracking and Data Network (STDN); and, the Aeronautics, Balloon and Sounding Rocket (AB&SR) program.

DEEP SPACE NETWORK (DSN)

The Voyager Neptune encounter was discussed earlier. The same DSN that provided tracking and data acquisition for Voyager enables mission operations for a wide variety of interplanetary and some Earth-orbital spacecraft. This network has a world-class capability for receiving transmissions from spacecraft operating in our outer solar system, and for performing the extremely accurate measurements necessary to navigate to the outer planets. The DSN is a unique capability. The United States is the only nation that operates spacecraft beyond the orbit of Mars. As a point of reference, Neptune is 25 times as far away as Mars. The DSN routinely receives data from over seven billion kilometers from Earth. Traveling at the speed of light, this data, from Pioneer 10, takes over six hours to reach Earth.

The DSN operates one of the largest planetary radar systems in the world. Scientists are able to map the surface of Venus, Mars, and Mercury and to observe the rings of Saturn, asteroids, and comets with this capability.

The primary elements of the DSN are three multi-antenna complexes positioned around the Earth at approximately 120-degree longitude intervals. These facilities are located near Goldstone, California; Madrid, Spain; and Canberra, Australia. They provide continuous observations of planetary spacecraft. The network is managed by the Jet Propulsion Laboratory (JPL).

The Magellan and Galileo spacecraft were launched in 1989. Magellan will study the planet Venus, and Galileo will probe the atmosphere of Jupiter and tour its family of satellites. In this and future years, the DSN will provide tracking and data acquisition for these missions as well as for older spacecraft such as Pioneer 10 and Voyager 2, which have both passed beyond the most distant known planets.

The unmatched capabilities of the DSN have resulted in our participation being sought in many international cooperative programs.

SPACEFLIGHT TRACKING AND DATA NETWORK (STDN)

Ten years ago, the STDN included 14 ground stations around the world. In anticipation of the TDRSS era, most of these stations have been closed. In 1989, the STDN was reduced from a network of seven stations to its current configuration of three. The achievement of the operational Space Network allowed NASA to complete its long-time plan to close or transfer to other agencies four ground stations: Hawaii; Guam; Ascension Island; and, Santiago, Chile. Only Bermuda, Dakar, and Merritt Island, Florida, remain. The Dakar station in Senegal is being retained temporarily as a TDRS backup for emergency communications during Shuttle launches. We are presently reviewing this effort to identify a probable closure schedule. The NASA station on Ascension Island, which we previously reported would be transferred to another agency, has instead been closed and is being dismantled.

This Committee previously expressed concern about NASA's ability to provide contingency command and data acquisition services to spacecraft in emergency situations. Since the completion of phasedown, there have been 32 spacecraft emergencies, all of which were resolved satisfactorily using the remaining NASA facilities. Most of these emergencies resulted from the rapid orbital decay of the Solar Maximum Mission before it re-entered. We believe that our ability to retain control of that spacecraft during this period demonstrated our capability to satisfy emergency requirements.

AERONAUTICS, BALLOON, AND SOUNDING ROCKET (AB&SR) PROGRAM

The AB&SR Program provides tracking, data acquisition and data processing for suborbital research activities and selected Earth-orbiting satellites. The program also provides Shuttle landing telemetry and

command services from Edwards Air Force Base in California. The AB&SR Program also operates a combination of fixed and mobile facilities from the Dryden Flight Research Facility to meet its diverse aeronautical mission objectives.

Mobile and fixed instrumentation systems for tracking, data acquisition, and safety requirements for sounding rocket and balloon launches are operated by the Wallops Flight Facility in Virginia. These systems are utilized in the operation of a worldwide program of scientific research. The telecommunications facilities at Wallops are also utilized to track Earth-orbital missions. An enhancement to the Wallops mobile facilities will be used in conjunction with the NASA Small Explorer program for data acquisition in geographic areas not covered by other Ground Networks facilities.

A tracking facility at the University of Alaska, Fairbanks, is also operated by the AB&SR Program. This facility will receive data directly from two foreign Synthetic Aperture Radar Satellites used to map the Earth resources. NASA will be receiving data from these satellites as part of its cooperative agreements with Japan and the European Space Agency (ESA).

COMMUNICATIONS AND DATA SYSTEMS PROGRAM

The Communications and Data Systems Program budget request for FY 1991 is $270 million. The elements of the Communications and Data Systems Program form the vital link between the data acquisition stations and the scientific users and project facilities. These funds are for the following functional elements: two communication systems, spacecraft mission control centers; data processing; and, national and international coordination of the electromagnetic frequency spectrum allocation process.

The Communications Program provides two Agency-wide communications systems. The real-time Space Operations communications are accommodated through the NASA Communications (NASCOM) Network. The other communication requirements are provided by the Program Support Communication Network (PSCN). These global systems interconnect NASA's foreign and domestic tracking and data acquisition stations; NASA's launch complexes, mission and network control centers; and, NASA's field centers, major contractors, investigator sites, and international partners.

A five-year capability upgrade of NASCOM is designed to meet the higher data rates and volume requirements of NASA missions scheduled through the mid-1990's.

In FY 1991, the PSCN will continue to service NASA programs and projects, such as the Space Shuttle, Space Station Freedom, and other science programs. NASA-wide video teleconferencing capabilities will also be expanded to increase accessibility and to economically accommodate additional users.

The Mission Control Program provides the control and performance analyses of NASA's unmanned Earth-orbiting spacecraft. These control facilities are the only means of instructing the spacecraft to make observations and measurements. A Multi-Satellite Operations Control Center (MSOCC) is employed when facilities can be shared. Other programs, like Hubble Space Telescope (HST), require separate dedicated control centers. In FY 1991, four control centers will monitor and control nine orbiting spacecraft.

Preparations of MSOCC for future missions, such as the Extreme Ultraviolet Explorer (EUVE), the Upper Atmospheric Research Satellite (UARS), and the many individual missions of the International Solar Terrestrial Physics (ISTP) program will continue. These preparations consist of developing software, data bases, and procedures that are unique for each mission. FY 1991 will also be the final study, planning, and design year for the Advanced X-Ray Astrophysics Facility (AXAF) and Small Explorers (SMEX) control systems prior to full-scale control center developments for these missions.

Two major types of activities are funded within the Data Processing Program: capture and processing of spacecraft data, and performing highly specialized computations required for flight dynamics. The latter includes trajectory design, orbit determination and adjustment, and spacecraft attitude determination.

Flight dynamics and mission support for in-orbit free flyer spacecraft and shuttle attached payloads will continue, including support to the International Ultraviolet Explorer (IUE), International Cometary Explorer (ICE), Earth Radiation Budget Satellite (ERBS), Dynamics Explorer (DE), and Cosmic Background Explorer (COBE). Funding to upgrade real-time computational capabilities for current and future missions is also part of the budget request. In FY 1990, launch and mission operations requirements on the flight dynamics system will be extended to include the Broadband X-Ray Telescope (BBXRT) and Gamma Ray Observatory (GRO).

For Space Station Freedom and Earth Observing System era activities, extensive system planning studies will be completed in 1990 for the Customer Data and Operations System (CDOS).

ADVANCED SYSTEMS PROGRAM

In the Space Operations budget, $20 million is for the Advanced Systems Program.

The Advanced Systems Program continues to focus on assessing and employing technological advances in telecommunications, electronic micro-circuitry, and computer sciences. These efforts are essential for the cost-effective application of new technology to meet future mission requirements. On-going work includes investigations of the data transfer and processing needs of future missions, studies of ground systems and telecommunication links to determine effective design approaches, and overall tradeoffs for the lowest life-cycle costs for future space mission communications.

In FY 1990, several Advanced Systems Program products became operational. For example, the work on low cost, high electron mobility transistor amplifiers allowed use of the full capability of the National Science Foundation's Very Large Array for receiving telemetry during the Voyager encounter with Neptune. Without this capability, cost and reliability issues would have prevented the use of the full array and significantly reduced the data obtained in the Neptune encounter.

Another example is the use of advanced coding techniques. These will provide needed substantial improvement in the Galileo telemetry data rate capability. Two factors are involved. The delay of the Galileo launch to October 1989 placed the spacecraft farther from Earth at its encounter. The other is the decay of Radioisotope Thermal Generator (RTG) power. Together these reduce the Galileo signal strength. These coding techniques restore one-third of the signal strength loss.

CONCLUSION

In summary, the long-awaited operational Space Network was achieved in FY 1989 with three TDRS spacecraft in geosynchronous orbit and meeting space mission operational requirements. The Santiago, Chile; Guam; Hawaii; and Ascension Island ground stations were closed. The Deep Space Network supported the Neptune encounter of Voyager 2 in August 1989 as well as the launches of the Magellan and Galileo missions.

The request of $889 million for FY 1991 is essential to meet the challenges on the horizon. These include: preparation for the TDRS-5 launch; continued TDRS spacecraft production; implementation of the vital Second TDRSS Ground Terminal; and, completion of design studies for the Advanced TDRSS spacecraft to sustain the Space Network for future missions. These challenges also include operation of the mission control and data capture system required by the Hubble Space Telescope and other missions, systems planning and preparation for the space station era, and continued network preparation for Ulysses, Mars Observer, and other future missions.

Emphasis is focused on sustaining our Space Network by providing redundancy in the ground terminal, and by ensuring TDRS spacecraft availability. The DSN will gain new capability through advancements in technology, including the use of Ka-band. The Communications and Data Systems Program is planning significant upgrades to meet the operational requirements of the space station era.

As the 21st century draws near, the space operations community must prepare for Space Station Freedom, the Earth Observing System, the Great Observatories, and other challenging projects leading to the human exploration missions of the Moon and Mars. Technically superior, responsive, and cost-effective mission capability is essential to achieve the objectives and benefits of these future missions.

To attain the objectives of these exciting NASA programs, the Space Operations Program must be sustained and supported. I urge the Subcommittee's full support of NASA's budget. I especially urge the support of NASA's institutional program.

Mr. Chairman, members of the Committee, this concludes my statement. Thank you for this opportunity to discuss with you NASA's Space Operations Program.

SPEECHES AND QUOTES

This section includes recent speeches by President Bush and NASA officials and notable quotes concerning specific aspects of the space program made over the last few years.

Citations are noted in the cover page for each speech.

THE WHITE HOUSE

Office of the Press Secretary
(Huntsville, Alabama)

For Immediate Release June 20, 1990

REMARKS BY THE PRESIDENT
AT MARSHALL SPACE FLIGHT CENTER

Huntsville, Alabama

2:26 P.M. CDT

THE PRESIDENT: Dick, Admiral Truly, I'm very glad to be here. Let me just say something very personal. I can't tell you how fortunate the country is to have Admiral Truly lead NASA through these very exciting times. I salute him and I'm very grateful to him. (Applause.)

And I'm pleased to be here with the Governor of this state. A man whose unwaivering support for the space program is so well-known. I want to thank Jack Lee, the director of this center and my tour guide today. I'm grateful to him. There is no quiz. If there was I would probably fail because I am mightily impressed with the dedicated NASA workers, men and women young and old, who are doing such a superb job on the cutting edge of science.

I was sorry we were a little late getting started. These arrangements affect everything. Even I couldn't find a parking place. (Laughter.)

Reminds me of my days in college. Everybody would gather around to get cooled off watching me strike out.

But nevertheless I really am pleased to be back in Alabama, back in Huntsville. And I'm very proud of this state, proud of this special facility. The Marshall Space Flight Center is the birthplace of America's first satellite, America's first space station -- and the world's first Moon rocket. And it was here with Saturn Five that humankind began its historic journey to the stars.

Because of these traditions, Huntsville has a special importance to America and indeed to the entire world. And it has a special importance to me, as well. It was to Huntsville that I journeyed in the fall of 1987, to give a campaign -- for me at least -- a first major address on space. And on that October day two and a half years ago I promised to create a National Space Council, chaired by the Vice President. I pledged to underwrite Mission to Planet Earth, to boost space science and to launch a dynamic new program of both manned and unmanned exploration of the Solar System.

And today I'm pleased to return to Marshall to report that we have made good on these promises. And we've done it the old-fashioned way -- done it the American way -- step-by-step, program-by-program, all adding up to the most ambitious and far-reaching effort since Marshall and Apollo took America to the Moon.

The Space Council I proposed is not only up and running, but under the dynamic leadership of our Vice President it's leading the way into the 21st century. Mission to Planet Earth -- a bold and unprecedented initiative to preserve our precious environmental heritage -- has been plucked off the drawing board and placed in the hands of the scientists who will make it happen. And now that the shuttle program has put America back in space, we stand at the dawn of a new era in space science, with wonders like that magnificent Hubble Space Telescope and the fantastic voyage of Galileo to

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Jupiter.

Exactly 11 months ago, I was at the Air and Space Museum in Washington to commemorate a special anniversary for you who work at the Marshall Space Flight Center -- the 20th anniversary of Apollo 11's thunderous journey to the Moon. And standing with Neil Armstrong and dozens of other astronauts, I announced three major space policy objectives: First, to have Space Station Freedom up before the century is out. (Applause) And second, for the new century, a permanent lunar base. And we're going back to the Moon, back to the future -- and this time -- back to stay. (Applause.)

And the third objective was refined last month in Texas, where I went to announce a new Age of Exploration, with not only a goal, but a 30-year timetable. I declared -- permit me to read it again -- before Apollo celebrates the 50th anniversary of its landing on the Moon -- the American flag should be planted on Mars. (Applause.)

Being first in space is not just America's dream -- it is indeed our destiny. And to see this happen, we're matching rhetoric with resources. Our budget proposes $15.2 billion for NASA -- an increase of nearly 25 percent -- and the largest increase for any major agency of the United States government. (Applause.)

Now for the bad news. Unfortunately, not everyone on Capitol Hill shares this commitment to investing in America's future. And last week, the House Appropriations Subcommittee for Space voted to pull the plug on this historic undertaking, completely gutting the seed money we proposed for the Moon-Mars mission.

But, you know, space used to be a bipartisan effort -- just a plain American effort. And the last time a President visited Marshall, John F. Kennedy compared those who were uncertain about America's leadership in space to those in Queen Isabella's Court who counseled, in effect, "Turn back. Leave the riches and rewards for other nations and braver hearts."

Some say the space program ought to wait -- that we should only go forward once the social problems today are completely solved. But history proves that that attitude is self-defeating. Had Columbus waited until all the problems of his time were solved -- the timbers of the Santa Maria would be rotting on the Spanish coast to this very day. And instead he went forward, he ventured forth -- and his travels brought Spain to the zenith of her stature as a nation.

Many an American schoolkid has read the story of Columbus' doubters, and shook their heads in disbelief that these naysayers could have been so shortsighted.

We must not let the children of the future shake their heads at our behavior. And right now, in the funding wars on Congress, we face a central question -- the question of whether America will continue to be a pioneering nation.

And when John F. Kennedy stood before the Congress in 1961 and spoke about the moon, he spoke to a nation of pioneers. Now some in Congress appear ready to give up on that pioneering spirit -- to turn their sights inward, to concede that America's days as a leader in space have passed.

Well I, for one, am not ready to give up. (Applause.) America has always been, and will always be, a nation of pioneers. I may not be around in the year 2019 -- but all of you guys will and most -- a lot of people out here in this marvelous, young, vigorous work force will. And on that special day 30 years from now, I want you to think back to the commitment that we made here today, as you look at the TV monitors -- maybe right here at Marshall -- and watch the first American plant his feet on Mars. It's going to happen. With your work and our support it is going to happen. (Applause.)

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During the Apollo era, America's space efforts grew at unprecedented rates. The government hired the biggest and the best scientific force in history, and colleges and universities swelled with applicants and graduates in science and engineering. And it produced a golden age of American technology and advancement -- an age that, today, we can recapture and begin anew.

Wernher Von Braun was the giant who, in a sense, put Huntsville on the map. And when someone asked him what it would take to build a rocket to reach the Moon, Von Braun replied simply: "The will to do it."

And so I'm here today at this monument to daring, this monument to imagination that Von Braun built -- and call on the American Congress to step forth with the will that the moment requires.

Don't postpone greatness. History tells us what happens to nations that forget how to dream. The American people want us in space. So let us continue the dream -- for our students, for ourselves, and for all humankind.

Thank you for your dedicated work to this great country of ours. God bless the United States of America. Thank you for this warm, warm welcome. Thank you very much. (Applause.) Thank you.

END 2:37 P.M. CDT

THE WHITE HOUSE

Office of the Press Secretary

EMBARGOED FOR RELEASE
UNTIL 11:40 A.M. CDT
12:40 P.M. EDT
FRIDAY, MAY 11, 1990

TEXT OF REMARKS BY THE PRESIDENT
IN TEXAS A &I UNIVERSITY COMMENCEMENT ADDRESS

Javelina Stadium
Texas A & I University
Kingsville, Texas

May 11, 1990

I'm honored to be in the home of the legendary Javelinas--the wild hogs. And I'm deeply honored to be speaking from the hallowed space on the playing field usually reserved for "Porky."

Javelinas aren't the only wildlife native to these parts. The mesquite outside Kingsville is also shot through with rattlesnake and deer. Doves rise on the warm gulf winds, soaring over the palms and red tile roofs of Texas A&I. And South Texas is a special place for the Bush family. We come down nearly every December to visit friends and hunt just outside Beeville--Berclair, to be exact. When I was an 18-year-old Naval Aviation cadet way back in 1943, I flew all over this country, and I loved it.

Like springtime itself, college commencements signal a time of change. Last week, at Oklahoma State, I spoke about America's new leadership role in the Atlantic Alliance. Tomorrow morning, at South Carolina, we'll be talking about change among the people of Eastern Europe--people yearning to emulate not only our standard of living--but also our standard of justice.

But democracy isn't just the wave of the present--it's the wave of the future. And as your generation assumes a leadership role in a free world that's growing bigger all the time--others will continue to look to our shores for leadership and direction. I have proposed that one of those directions be space.

The American adventure has always had the capacity to inspire others and to astonish the world--the voyages of Columbus; the Declaration of Independence; the taming of a continent; the invention of flight.

America's democracy is the world's greatest experiment in freedom and diversity, an ongoing experiment that continues to unleash the creative energies of the world's most diverse population. It is what took American pioneers to the Moon and back. It is what will take you as far as your dreams can soar.

Like Texas itself, A&I is also a place of pioneers. The first four-year college in South Texas. A leader in bilingual education, with the first such doctoral program in the U.S. Home to research and innovations from natural gas engineering to snake venom to the Rio Star grapefruit. And many of you are yourselves pioneers--the first in your families ever to attend college.

In America's unique democratic heritage, our pioneers were not commissioned by kings. Our pioneers commissioned themselves--and took off! We are a searching people, future-oriented, impelled to push on. After graduating college I took my family west, looking for a country to test ourselves and our dreams. We found it in Texas, with enough opportunities to last many lifetimes.

Of course, Texas has always had its share of pioneers and visionaries. One was Sam Houston. Where others saw empty plains and dust, he saw farms, and ranches, and towns. Where others saw obstacles, he saw opportunity.

But Houston could scarcely have imagined that, little more than a hundred years after his death, the entire planet would hold its breath as his name became the first word ever uttered on the plains and dust of

another world.

It was July 20, 1969. And although Apollo 11 had just survived one of the most harrowing landings in the history of space, the voice of Neil Armstrong was confident, strong, American. He said: "Houston: Tranquility Base here. The Eagle has landed." Eight words. And the world was changed forever.

When America accepted the Apollo challenge, we rolled up our sleeves and took on a daunting and dangerous job. Apollo 11 showed we could meet our commitments to ourselves and to the world--proof that democracy could triumph as decisively in peace as it had in war. It lifted the spirits of a generation, and raised forever the horizons of the human race.

Last summer, in a speech commemorating the 20th anniversary of the Apollo Moon landing, I announced three major space policy objectives: First, to have Space Station Freedom up before the century is out. Second, for the new century, a permanent lunar base: "Back to the Moon, back to the future--and this time--back to stay." And third, a manned expedition to Mars.

Together, these objectives form the cornerstone of my Administration's far-reaching plan for investing in America's future. Our space program will help rekindle public interest in science and mathematics, and revitalize an area of our educational system that has become disturbingly weak. In fact, one of the education goals we announced in January is to make the United States first in math and science by the year 2000. But our space program will do more. It will revolutionize everything from computers to communications, from medicine to metals, regaining and retaining America's high-tech competitive edge. It will create new technologies, new industries, and new jobs.

It's an adventure I hope many of you will be part of. And it's an adventure that's already underway.

The Space Shuttle is back and ushering in a new era in space. And it's led by a talented new generation--scientists like A&I Professor John

Linder, who is working here to improve Shuttle communications; Shuttle engineers like Ruben Zavala, A&I Class of 1977; avionics experts like Promitivo Perez, Class of 1971; and new American heroes like Franklin Chang-Diaz, NASA's first Hispanic astronaut.

You are coming of age during a Golden Age of space. And there's no better example of this than the miracle now orbiting 380 miles above Kingsville--the Hubble Space Telescope. It will see to the furthest reaches of the universe, to the very edges of time. And it's hoped that the telescope will see objects so clearly that, in theory, it could pick out the writing on a dime--100 miles away.

And even while Galileo and Hubble begin looking out across space--another array of new satellites will be looking back at Earth--and taking the pulse of the most important planet in the universe.

We call this initiative "Mission to Planet Earth." It's an effort of such magnitude, it dwarfs everything in the past--a worldwide study of the complex interactions between land, sea, ice and air--as well as between the Earth and the Sun. It's an effort of global interest, in which we're inviting other nations to join. As Chairman of the National Space Council, the Vice President has just returned from Europe, where our allies expressed serious interest in both "Mission to Planet Earth" and in our continuing exploration of the Solar System.

Initiatives like these mark a critical investment in America's future. They will help protect the environment, fuel an educational renaissance, and hone America's competitive edge.

But the importance of the space program--especially the manned space program--goes deeper than that. Throughout our history, America has been a nation of discoverers. It is part of our national character--part of our democratic heritage. In fact, Monday marks the day in 1804 when Meriwether Lewis and William Clark set out across the Mississippi to map much of what was to become the great American West. Despite Thomas Jefferson's love of machines--it's hard to imagine his sending a robot out alone to describe the wonders of the American Rockies and the Pacific coast. In the American experiment--in the experiment called

democracy--there will always be a place for individual men and women with imagination and daring.

Our Nation's quest for the unknown took American pioneers from the bluffs of the Mississippi to the mountains of the Moon. But today, we're no longer just asking for the Moon. We've been there. We're looking further, to carry the American adventure to wherever opportunity, curiosity, and need will take us.

It's time to open up the final frontier. There can be no turning back. America's space program is what civilization needs to begin this journey, and to perfect the commitment to go beyond. Each time we go to the frontier and beyond, we bring back more than we hoped for. This time we have the chance to bring back more than we can imagine.

Our 1991 budget is proof positive of America's commitment to an active, exciting and continuing presence in space--to America's leadership in space. Our budget proposes $15.2 billion for NASA, an increase of 24 percent--almost $3 billion--which is the largest increase for any major agency of the government.

But leadership in space takes more than just dollars. It also takes a decision. And I'm announcing one today.

We stand at a halfway point in our exploration of the immediate solar system--the planet Earth, its Moon, and the terrestrial neighborhood. Thirty years ago, NASA was founded and the space race began. And 30 years from now I believe Man will stand on another planet. And so I am pleased to return to Texas today to announce a new Age of Exploration, with not only a goal but also a timetable: I believe that before Apollo celebrates the 50th anniversary of its landing on the moon--the American flag should be planted on Mars.

Up beneath the dome of the United States Capitol--where decisions about our space program will be made in the coming weeks--the American adventure is told in stone, a tableau of U.S. history carved around the rim of the dome itself. It begins with Columbus' arrival in the New World and ends with the first flight of the Wright brothers'

plane.

But they got it wrong. The Wright brothers flight doesn't mark the end of the American adventure, but the beginning of a new chapter--a neverending story--a story about a democracy where anything is possible, and where no dream is too large.

We live in a century that began with great promise and hope for the idea we call democracy, then only beginning to assume an important place on the world stage. That hope has been fulfilled--and surpassed--beyond the wildest dreams of our founders. And the promise of democracy is beginning to be tasted by more people in more places than ever before. It is their inspiration. And it is our strength, our heritage, and our future.

And so as this century closes, it is in America's hands to help determine the kind of people, the kind of planet, we will become in the next. We will leave the Solar System and travel to the stars. Not only because it is democracy's dream, but because it is democracy's destiny.

Around campfires, by moonlight and starlight across the ages, men and women have turned their gaze skyward and dreamed an ancient dream. And somewhere in America today, maybe here in this stadium, there is a young man or woman who, like Neil Armstrong, will seize this dream and change the world for all time. I believe, I truly believe, that the Class of '90 will leave footprints not only in the sands of Texas--but also in the sands of time--and ultimately on the plains of Mars.

You who have lived these past four years in Kingsville know a lot about the sky. The plains of South Texas are as flat as the sea--a land without hills or impediments, a land of limitless horizons and dreams to match. It is exactly the kind of nighttime sky where the cream of America's youth--the cream of Texas A & I--can point confidently to the stars--to eternity--and to their own future, the future of this great Nation, and the future of free people everywhere.

THE WHITE HOUSE

Office of the Press Secretary

For Immediate Release July 20, 1989

REMARKS BY THE PRESIDENT
AT 20TH ANNIVERSARY OF
APOLLO MOON LANDING

The Steps of the Air and Space Museum
Washington, D.C.

10:30 A.M. EDT

THE PRESIDENT: Thank you all very, very much. And thank you, Mr. Vice President, for your introduction and for your introduction and for undertaking to head the National Space Council and for -- already for demonstrating your skill for leadership there.

And thanks to all of you, who have braved the weather to join us today. Behind me stands one of the most visited places on Earth -- a symbol of American courage and ingenuity. And before me stand those on whose shoulders this legacy was built -- the men and women of the United States astronaut corps.

And we are very proud to be part of this unprecedented gathering of America's space veterans -- and to share this stage with three of the greatest heroes of this or any other century -- the crew of Apollo 11.

It's hard to believe that 20 years have passed. Neil and Buzz, who originated the moonwalk 15 years before Michael Jackson ever even thought of it. (Laughter.)

And Michael Collins -- former director of this amazing museum -- and the brave pilot who flew alone on the dark side of the Moon, while Neil and Buzz touched down. Mike, you must be the only American over age 10 that night who didn't get to see the Moon landing. (Laughter.)

And later this evening, after the crowd disperses and the sun goes down, a nearly full Moon will rise out of the darkness and shine down on an America that is prosperous and at peace. And for those old enough to remember that historic night 20 years ago -- step outside tonight with your children or your grandchildren. Lift your eyes skyward, and tell them of the flag -- the American flag -- that still flies proudly in the ancient lunar soil.

And for those who were not yet born, or then too young to recall -- you who are the children of the new century -- raise your eyes to the heavens and join us in a great dream -- an American dream -- a dream without end.

Project Apollo. The first men on the Moon. Some called it quixotic, impossible -- had never been done. But America dreamed it. And America did it. And it began on July 16th, 1969. The sun rose a second time that morning as the awesome fireball of the Saturn Five lifted these three pioneers beyond the clouds. A crowd of one million -- including half of the United States Congress -- held its breath as the Earth shook beneath their feet -- and our view of the heavens was changed forevermore.

Three days and three nights they journeyed. It was a perilous, unprecedented, breathtaking voyage. And each of us remember the night.

Barbara and our daughter Dorothy were with me in our red

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brick house right here on the outskirts of Washington, where we moved up here to represent Houston in the United States Congress. Our 12-year-old kid, Marvin, was on a trip out West with family friends and remembers stopping at a roadside motel to watch. Second boy, Jeb, 16 that summer, teaching English and listening by radio in a small Mexican village, where electricity had yet to arrive.

The landing itself was harrowing. Alarms flashed -- and a computer overload threatened to halt the mission while Eagle dangled thousands of feet above the Moon. Armstrong seized manual control to avoid a huge crater strewn with boulders. With new alarms signalling a loss of fuel -- and the view now blocked by lunar dust -- Mission Control began the countdown for a mandatory abort.

America -- indeed the whole world -- listened -- a lump in our throat and a prayer on our lips. And only 20 seconds of fuel remained. And then out of the static came the words: "Houston. Tranquility Base here. The Eagle has landed."

Within one lifetime, the human race had traveled from the dunes of Kitty Hawk to the dust of another world. Apollo is a monument to our nation's unparalleled ability to respond swiftly and successfully to a clearly stated challenge -- and to America's willingness to take great risks for great rewards.

We had a challenge. We set a goal. And we achieved it.

So today is not only an occasion to thank these astronauts and their colleagues -- the thousands of talented men and women across the country whose commitment, creativity, and courage brought this dream to life. It's also a time to thank the American people for their faith -- because Apollo's success was made possible by the drive and daring of an entire nation committed to a dream.

In the building behind me are the testaments to Apollo and to what came before -- the chariots of fire flown by Armstrong, Yeager, Lindbergh, and the Wrights. And in the National Archives -- across the great expanse of grass -- are preserved the founding documents of the idea that made it all possible -- the world's greatest experiment in freedom and diversity.

And here -- standing between these twin legacies -- is a fitting place to look forward to the future.

Because the Apollo astronauts left more than flags and footprints on the Moon. They also left some unfinished business. For even 20 years ago, we recognized that America's ultimate goal was not simply to go there and go back -- but to go there and go on.

Mike Collins said it best: "The Moon is not a destination -- it's a direction."

And space is the inescapable challenge to all the advanced nations of the Earth. And there's little question that, in the 21st century, humans will again leave their home planet for voyages of discovery and exploration. What was once improbable is now inevitable.

The time has come to look beyond brief encounters. We must commit ourselves anew to a sustained program of manned exploration of the solar system -- and yes -- the permanent settlement of space. We must commit ourselves to a future where Americans and citizens of all nations will live and work in space.

And today, yes, we are, the U.S. is the richest nation on Earth -- with the most powerful economy in the world. And our goal is nothing less than to establish the United States as the preeminent spacefaring nation.

From the voyages of Columbus -- to the Oregon Trail -- to

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the journey to the Moon itself -- history proves that we have never lost by pressing the limits of our frontiers.

Indeed, earlier this month, one news magazine reported that Apollo paid down-to-earth dividends -- declaring that man's conquest of the Moon "would have been a bargain at twice the price." And they called Apollo "the best return on investment since Leonardo da Vinci bought himself a sketch pad." (Laughter.)

In 1961, it took a crisis -- the space race -- to speed things up. Today we don't have a crisis. We have an opportunity.

To seize this opportunity, I'm not proposing a 10-year plan like Apollo. I'm proposing a long-range, continuing commitment.

First, for the coming decade -- for the 1990's -- Space Station Freedom -- our critical next step in all our space endeavors.

And next -- for the new century -- back to the Moon. Back to the future. And this time, back to stay. (Applause.)

And then -- a journey into tomorrow -- a journey to another planet -- a manned mission to Mars. (Applause.)

Each mission should -- and will lay the groundwork for the next. And the pathway to the stars begins, as it did 20 years ago, with you -- the American people. And it continues just up the street there -- to the United States Congress -- where the future of the space station -- and our future as a spacefaring nation -- will be decided.

And yes, we're at a crossroads. Hard decisions must be made now as we prepare to enter the next century.

As William Jennings Bryan said -- just before the last turn of the century: "Destiny is not a matter of chance -- it is a matter of choice. It is not a thing to be waited for -- it is a thing to be achieved."

And to those who may shirk from the challenges ahead -- or who doubt our chances of success -- let me say this:

To this day, the only footprints on the Moon are American footprints. The only flag on the Moon is an American flag. And the know-how that accomplished these feats is American know-how. What Americans dream -- Americans can do.

And 10 years from now -- on the 30th anniversary of this extraordinary and astonishing flight -- the way to honor the Apollo astronauts is not by calling them back to Washington for another round of tributes. It is to have Space Station Freedom up there, operational, and underway -- a new bridge between the worlds -- (applause) -- and an investment in the growth, prosperity and technological superiority of our nation.

And the space station will also serve as a stepping stone to the most important planet in the solar system -- Planet Earth.

As I said in Europe just a few days ago, environmental destruction knows no borders. A major national and international initiative is needed to seek new solutions for ozone depletion, and global warming, and acid rain. And this initiative -- "Mission to Planet Earth" -- is a critical part of our space program. And it reminds us of what the astronauts remember as the most stirring sight of all. It wasn't the Moon or the stars, as I remember. It was the Earth -- tiny, fragile, precious, blue orb -- rising above the arid desert of Tranquility Base.

The space station is a first and necessary step for sustained manned exploration -- one that we're pleased has been

endorsed by Senator Glenn, and Neil Armstrong, and so many of the veteran astronauts we honor today. But it's only a first step.

And today I'm asking my right hand man, our able Vice President, Dan Quayle, to lead the National Space Council in determining specifically what's needed for the next round of exploration -- the necessary money, manpower, and material -- the feasibility of international cooperation -- and develop realistic timetables, milestones along the way. The Space Council will report back to me as soon as possible with concrete recommendations to chart a new and continuing course to the Moon and Mars and beyond.

There are many reasons to explore the universe, but 10 very special reasons why America must never stop seeking distant frontiers -- the 10 courageous astronauts who made the ultimate sacrifice to further the cause of space exploration. They have taken their place in the heavens, so that America can take its place in the stars.

Like them, and like Columbus, we dream of distant shores we've not yet seen.

Why the Moon? Why Mars? Because it is humanity's destiny to strive, to seek, to find. And because it is America's destiny to lead.

Six years ago, Pioneer 10 sailed beyond the orbits of Neptune and of Pluto -- the first man-made object to leave the solar system. Its destination unknown. It's now journeyed through the tenures of five Presidents -- four billion miles from Earth.

In the decades ahead, we will follow the path of Pioneer 10. We will travel to neighboring stars, to new worlds, to discover the unknown. And it will not happen in my lifetime, and probably not during the lives of my children, but a dream to be realized by future generations must begin with this generation. We cannot take the next giant leap for mankind tomorrow unless we take a single step today. (Applause.)

To all of you here, our able director of NASA and others who've served so well -- to all of you here -- and especially the astronauts -- we wish you good luck in your quests, wherever that may take you. Godspeed to you, one and all. And God bless the United States of America.

Thank you all very, very much. (Applause.)

END 10:46 A.M. EDT

OFFICE OF THE VICE PRESIDENT

Embargoed until delivered -- 9:40 AM (MDT) - April 10, 1990

TEXT OF REMARKS BY THE VICE PRESIDENT

SIXTH NATIONAL SPACE SYMPOSIUM
UNITED STATES SPACE FOUNDATION

Broadmoor Hotel
Colorado Springs, Colorado

Good Morning. Thank you, Jim (Hill) for the warm introduction. It is a pleasure to be back here at the Broadmoor. This beautiful city of Colorado Springs is such an important center for America's space activities. Here, under Cheyenne Mountain, and at Falcon and Peterson Air Force Bases -- the men and women of Space Command are at work, 24 hours every day, tracking, monitoring and controlling spacecraft. These people are the unsung heroes of our space program.

And, of course, the Space Foundation is based here. Since 1983, you have been a cornerstone of our thinking and planning for space. And you have dedicated yourselves to inspiring our fellow citizens to sustain their commitment to our space efforts.

Today is special. For today the Space Shuttle will -- we hope -- leave earth to carry the Hubble Space Telescope 380 miles to earth orbit. We have waited a long time for this launch -- but if all goes well today, the wait will have been worth it. For the Hubble telescope,

along with the other Great Observatory satellites, which will soon follow it into space, will revolutionize our scientific knowledge.

The Hubble will mark a scientific advance comparable to Galileo's invention of the telescope almost 400 years ago. It will rewrite our children's textbooks, and begin a whole new chapter in our understanding of time and space. It will help lead us to answers to some of the most ancient and fundamental questions -- such as the age of the universe, and it will allow the human eye to penetrate the darkness of space to find objects only so far imagined. As one scientist has said, "We'll be like a little nearsighted child in a classroom who is given a pair of glasses and at last can see what the teacher has been writing on the blackboard."

I'm struck by the kind of excitement the Hubble launch has already generated -- not just among the space community, but among Americans at large. The Hubble is generating excitement like the Voyager sailing past Neptune during the dog days of August, transmitting its beautiful pictures back to us. We neeed to return excitement to our space program.

There are skeptics and naysayers who claim that Americans have lost their taste for exploration, for discovery, for challenging the limits of our knowledge.

They are wrong. The thrill I experienced at the Jet Propulsion Laboratory when Voyager's pictures came in was shared by millions of Americans. And it is this human quest for discovery, for excitement, a quest inspired by a sense of wonder and awe, that leads us to reach out, to know what can be known, to see all that can be seen, to go anywhere there is something to be discovered, and to follow to the limits of our imagination. It is this quest that lies at the basis of our commitment to space exploration and discovery.

During my year of serving as Chairman of the National Space Council, I've become more convinced than ever that our space program is fundamental to the very mission of America. We have always been an exploring nation. From the Oregon Trail to the dunes of Kitty Hawk, part of America's greatness was embodied in the willingness to break the bonds of our tradition and to explore new spaces. That is why the President and I believe that in the 21st Century, America must be the world's preeminent spacefaring nation.

But we explore space not only because we are a nation of explorers. We also explore space because of the real, tangible benefits we derive from our space program.

The Space Foundation's terrific television spots -- the series called "Space, What's in it for You" -- highlight many of these benefits:

-- new medical technologies to help the deaf, the blind and the disabled, and that allow us to perform previously unimaginable feats like bone marrow transplants and laser surgery;

-- technologies that are revolutionizing our communications capabilities;

-- technologies that will lead to better crop production;

-- and even everyday items like the athletic shoes that seem to be replacing every other kind of shoe in this country!

But space makes so many other contributions. Space activities support our efforts to improve our children's education. By providing exciting space achievements, heroic space pioneers, and new discoveries, our space program helps create the incentives that make our young people want to excel in math and science. Improved math and science education is absolutely fundamental for our nation's future.

Space is also vital to our efforts to preserve and protect the environment here on earth. The Landsat satellite system, which the Space Council reviewed last spring, has been a primary source of our current understanding of environmental change. And the new Earth Observing System, which we will begin to build in 1991, will provide us with the in-depth knowledge we need to understand global climate change.

Space also has helped us build a more peaceful and stable world. For example, space systems enable us to verify arms control treaties. And as communications satellites have linked peoples around the globe more closely, the communications made possible by satellites have contributed to the fight against repression and totalitarianism.

But we have only begun to enjoy the concrete benefits of space exploration. I recently had dinner with a number of the "senior statesmen" of the space community. They were all very enthusiastic about what the future holds for man if we continue and renew our commitment to space. They told me, for example, that in the next century space may be key to allowing us to satisfy our energy needs from space without damaging the environment; providing us with increased access to rare and essential metals and minerals;

and allowing us to develop new information services which could further the revolution in communications which has already begun. And, of course, in the next century, research in space could lead to new medicines or medical treatments of incalculable benefit to mankind.

You and I understand all these benefits and opportunities that space provides. But what about a key participant in this whole enterprise -- the taxpayer who is footing the bill. Have we done enough to explain the significance and meaning of these accomplishments to the average citizen? The average taxpayer needs to be shown that there is a link between our space expenditures -- his space expenditures -- and the quality of his or her life. We simply need to do a better job.

As you know, the National Space Council, which I chair, has developed a five-part strategy for space, designed to cut across the traditional divisions. I am pleased to see that you have structured your agenda for this conference along the lines of these five strategy elements. We will be listening to your discussions here, and look forward to hearing your conclusions and recommendations.

Let me spend a just a few minutes reviewing for you what we are doing in each of these areas. First, we are working to develop space launch capabilities as a national resource to make access to space routine and affordable in the future. Where would highway transportation be today if we had built only those roads and bridges that could be fully justified on the basis of a specific need at the time? Needless to say, we did not do that. Space access is the essential first step in our national space program.

Second, we are committed to opening the frontiers of space through both manned and unmanned exploration. We are well underway with in-depth unmanned exploration of the Solar System. Viking, Voyager, Magellan, Galileo and, today, Hubble are our unmanned voyages of discovery continue to be spectacular accomplishments. And the initiative to return to the Moon, then go on to explore Mars, is this Administration's first major space decision has given shape to the manned space program.

The third element of our strategy is to intensify our use of space to solve problems here on Earth. I already talked about the important benefits we are deriving and can derive here on earth from space and would only repeat the need to help explain these benefits to our fellow citizens. Dick Cheney spoke to you yesterday about the importance of the Strategic Defense Initiative.

I wholeheartedly agree with him. The Brilliant Pebbles program, which uses technologies available today, is a deterrent we can't afford to be without.

Fourth, we will want to ensure the freedom of space for exploration and development. Space will become to the future what oceans have always been; highways to discovery and commerce. But the sea lanes can also be dangerous. They can be open or closed. They can even be used as springboards for attack. For these reasons we must ensure the freedom to use space for exploration, for development, for ourselves and for all nations.

The final element of our strategy is to foster our economic well-being by capitalizing on the unique environment of space. Until a few years ago, space was almost exclusively the domain of governments. Now we are committed to bring the energies of America's marketplace to space. Our challenge is to create an environment which encourages the development of new, private sector space efforts.

Let me expand on this point for a minute. It was America's technology that led the way in space. It was America's genius that put a man on the moon. And it will be America's entrepreneurial spirit that keeps us first in space. The United States is the only nation with a non-governmental private space sector. Last week's successful

launch of Pegasus is a classic demonstration of the wisdom of encouraging private investment. However, our space industries must be able to compete against foreign government-owned or supported industries. And very high initial investments are often needed to introduce new space products. These cannot be allowed to form barriers that keep us from developing new markets for the good of all Americans. In such cases, the government must take positive actions.

Let me be very clear: encouraging a competitive private sector is in America's long term self interest. And space and space enterprises are a traditional American strength. As Chairman of the National Space Council, I can assure you that we intend to keep it that way. I am pleased by the recent agreement in principle reached with Japan that will allow U.S. companies to compete for Japanese satellites. But other decisions, ranging from new spaceports to foreign cooperative programs, are still pending.

For this reason, the Space Council has initiated a high level, fast paced policy review. Later this year, we will be ready to announce a policy framework which outlines the appropriate government role in ensuring that America remains the world leader in space.

You know, as someone who grew up in the 1960's, seeing America first in space seems natural to me. After all, when my parent's generation was young, seeing a man on the moon was just a dream in some fantasy science fiction story. My generation saw it happen, though. And today, our children expect things that are beyond many of our dreams.

Last year, I visited the Space Camp in Huntsville, Alabama. During my visit a young man, 17 years old, told me, "Mr. Vice President, my generation is going to plant the American flag on Mars." I think he is right.

Like you, President Bush and I are committed to making that young man's dreams come true. Working with you, we can turn their dreams into reality -- for the benefit of ourselves and our children, and for the benefit of people today and future generations all over the world.

Thank you and God Bless you.

NASA
National Aeronautics and Space Administration

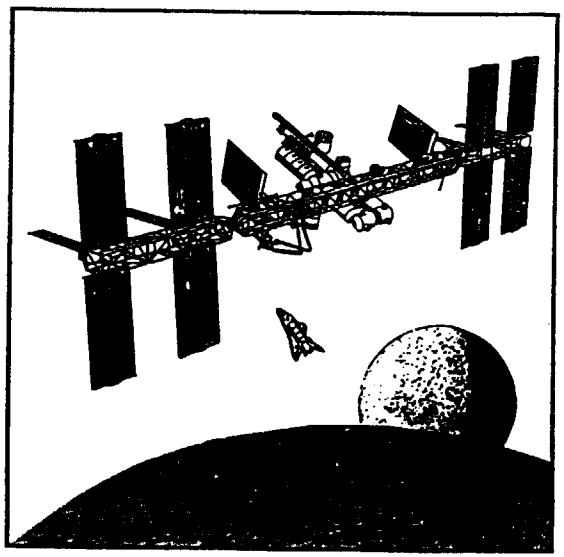
Hold for Release Until
Presented by Witness

June 28, 1990

Subcommittee on VA—HUD—Independent Agencies

Committee on Appropriations

United States Senate



Statement by:
Admiral Richard H. Truly
Administrator

101st Congress

STATEMENT OF

RICHARD H. TRULY
ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

BEFORE THE

SUBCOMMITTEE ON VA-HUD-INDEPENDENT AGENCIES

COMMITTEE ON APPROPRIATIONS
U. S. SENATE

June 28, 1990

Madam Chair and distinguished members of the Subcommittee:

I am pleased to have the opportunity to testify before you on the importance of mathematics and science education in America. NASA supports a strong education program which seeks to kindle students' instinctive interests in airplanes, spacecraft, astronauts, and space exploration to draw them into the disciplines of mathematics, science and technology.

I am especially pleased by the presence and testimony during the first Panel of two close colleagues -- Dr. Allan Bromley, the Assistant to the President for Science and Technology; and Dr. Erich Bloch, Director of the National Science Foundation. Although personal circumstances prevented Admiral Watkins, Secretary of Energy; and Dr. Ted Sanders, Under Secretary, U.S. Department of Education, from appearing today, they have sent very able people to represent them.

Each of our agencies has a vested interest in and national responsibility for improving mathematics, science, and technology education. Individually, our agencies' education programs reflect our special missions, specialized workforces and unique facilities. Collectively, we are using several promising mechanisms to work together. An extremely important collaborative mechanism entails NASA membership on the Education and Human Resources Committee under the Federal Coordinating Council for Science, Engineering and Technology (FCCSET), sponsored by the Office of Science and Technology Policy. Another includes a recently negotiated Memorandum of Understanding on Science and Mathematics Education between NASA

and the Department of Energy. We also consult with the National Science Foundation and the Department of Education on a number of science and math education areas.

At no time in our history has education been so prominent on the national agenda. The statistics that mark the education problem in this country have been talked and written about over and over. But quoting statistics won't make the problem go away. Statistics won't open our children's eyes to the excitement of math, science, and technology. We will need to take action to stimulate and implement educational reform.

Our country urgently needs a continuing supply of young scientists, engineers, and technicians to keep our nation economically and technologically competitive. The compelling national education goals set by the President and the Governors require that we develop more innovative educational outreach strategies, while retaining our proven educational programs. We cannot simply continue to do what we have always done, because that has proven not to be good enough.

I am tempted to tell you about NASA's exciting portfolio of education programs coordinated through the Educational Affairs Division of our External Relations Office and in concert with our nine field centers. This comprehensive array of educational programs parallels the diverse nature of our aeronautics, space science, and exploration programs. Our education budget is not large, but the unique aerospace content of our education programs provides great popular appeal. This and the participation in our programs by the professional education community makes our programs stand tall among all of the Federal agencies that conduct science and education outreach programs.

I would like to focus my remarks today on the educational policy changes that I have initiated to strengthen NASA's education program and on the new education outreach programs that have been started during my Administration.

Refocussed Education Policies

I have made several policy changes to improve the design and execution of our NASA Educational Affairs Program. The first change has been to clarify the mission of our external education program. The new mission statement directs NASA to conduct and promote aerospace education programs and activities, from elementary school through graduate school, in order to assist and inspire more of today's students to prepare themselves for careers in science, engineering, and technology.

NASA's educational strategy, in order to achieve this goal, is comprised of three elements designed: 1) to capture student

interest in science, mathematics, and technology at an early age; 2) to channel more students into science, engineering and technology career paths; and 3) to enhance the knowledge, skills, and experiences of precollege teachers, college and university faculty, and other educators.

NASA's educational strategy is closely aligned with the six national educational goals the President and the Governors have established for the nation. While we will address all of the President's goals, NASA is structured to make the greatest contribution to four. Those four goals concern increasing the high school graduation rate; enhancing student achievement and citizenship; making U.S. students first in science and mathematics achievement; and advancing adult literacy and lifelong learning .

To ensure a close coupling of NASA's activities with the President's goals, I have designated the Director of our Educational Affairs Division to be a member of the White House Education Summit Follow-up Committee.

In pursuing our educational programs, NASA leverages its aeronautics, space science and applications research programs to yield a wide range of activities, experiences and materials for use in the educational community. We deliver these educational resources to the community through a variety of ways. We have a small unique team of aerospace education specialists who conduct classroom and assembly lectures and give demonstrations. We develop supplementary curriculum materials and administer national student competitions. We provide fellowships and internships. We conduct and participate in educational conferences and conventions. We offer urban community education enrichment programs. We maintain computer data bases on aerospace education. And we conduct satellite video broadcasts to teachers around the country.

I have established NASA's educational programs as a separate line item, beginning in the FY 1990 NASA budget. Listed under the title of Academic Programs, this additional measure elevates and identifies education as one of NASA priorities. Our FY 1991 budget request for education is $50.1 million, representing an increase of 35 percent over the current $37.0 million program level.

Recently we began a process to update and convert NASA's existing Five-Year Educational Affairs Plan into a ten-year plan. In this way, the plan will correspond to the time frame of President's national education goals for the 1990-2000 decade. In addition to maintaining the three elements of NASA's fundamental educational strategy, this more comprehensive plan, entitled Science and Technology Literacy

for the 21st Century (STL-21) will also include the following guidelines:

* We will emphasize educational programs and projects that leverage our resources by having a multiplier effect on the target groups we seek to reach.

* We will substantially increase the number of underrepresented minorities, women, and handicapped participants in all of our educational programs.

* We will target all students, rather than just the traditional 5 percent who are highly motivated toward science and technical careers.

* We will use and promote increased application of educational technologies to deliver aerospace education programs. Among such programs are live and recorded lessons from the astronauts on appropriate Space Shuttle missions; satellite video broadcasts; expanded use of NASA Select for educational broadcasts; computer access information systems; laser disc technology; and educational software development.

* We will form additional partnerships with other Federal agencies, private industry, foundations and other organizations to coordinate educational resources.

New Outreach Initiatives

NASA's educational programs have one principal goal -- to increase the number of scientists, engineers and technicians available to contribute primarily to the civilian aerospace workforce, and secondarily, to other workforce segments of our economy. But to meet this goal, we need to have a comprehensive educational outreach program, from the elementary level through university level. The three elements of NASA's educational strategy have guided the development and evaluation of all NASA education programs. First, we know that students become interested in science, math and technology at an early age. Conversely, they can be "turned off" at an early age. Therefore, it is important to me that NASA has a broad outreach program to capture a student's interest in science, mathematics and technology at the elementary and middle school levels by using aeronautics and space as a vehicle of excitement. Second, once we have captured that interest, it is important to have a broad and diverse set of informal educational experiences that channel secondary and university students into science and engineering career paths. Third, it is not enough to have a comprehensive program only for students. We must leverage our resources and help our teachers and university faculty enhance and update their knowledge, skills and

experiences, thus providing a significant multiplier effect on their students.

Early in my tenure, I asked my staff to analyze our existing educational programs in light of the three elements of NASA's educational strategy just discussed -- capture, channel, and enhance. I challenged them to look for new ways to use NASA's exciting missions, unique talents of our staff and our unique facilities to determine how we could do more to help alleviate this national crisis in education. I would like to share with you some specific steps we are taking in this regard. And I would like to emphasize that I am providing only highlights of our programs in these three areas. In total, NASA is conducting over 150 separate educational programs; I am describing only a few.

Capture Student Interest in Science, Math and Technology at an Early Age

The Space Exposed Experiment Developed for Students project (SEEDS) is an example of one of our unique educational activities designed to stimulate student interest in science, mathematics and technology. This cooperative project between NASA and the Park Seed Company involved distributing to teachers some 12 million Rutgers tomato seeds that were returned to Earth after having been in orbit on NASA's Long Duration Exposure Facility (LDEF) for over five years. The space seeds, along with a set of control seeds and a Teachers' Guide, has enabled students to compare the seeds for germination time and rates, seedling vigor, phototropic responses and fruit products. More advanced students are performing chromosome and population genetics studies. Through this project, students are learning how to design their own experiments, test hypotheses, collect and classify data, make decisions, and report results. Since April of 1990, we have distributed over 100,000 space tomato seeds kits to elementary and high school teachers in every state.

By bringing together the talents of astronomy mission managers, the Space Shuttle astronaut crew of STS-35, and our educational staff, we are piloting a new approach of teaching live lessons from space. Our pilot effort will be applying the science of the Astro-I observatory to a topic taught at the middle school level -- the electromagnetic spectrum. This pilot effort involves teaching a lesson on the spectrum to students assembled at the Goddard Space Flight Center and the Marshall Space Flight Center. The educational lesson taught from the Columbia will be edited into an educational video tape that will be supported by a teacher's guide, slide set and poster so that the educational value can be shared in classrooms throughout the nation for years to come. More importantly, this pilot program forms the basis of a new working group I

have established to systematically develop educational plans related to specific NASA missions for the 1990's.

My view is that we must concentrate more and more on younger and younger people. It is not too early in kindergarten and even before to have programs to teach parents to do simple things to make their children receptive to the excitement of math, science, and technology. We talk a lot about the brilliance of some of our university students and the achievements of some of our high performers. At the same time, we cannot afford to lose the attention of the majority of our American youngsters where math and science are concerned.

Channel More Students into Science and Engineering Career Paths

Improved education for minorities, women and the handicapped will increase the availability of scientists and engineers for future programs and thus will prove to be one of the real solutions to the nation's educational competitiveness problem. The demographics of the work force is changing and if we cannot excite more young Black, Hispanic and female children about math and science, then we are not going to have adequate manpower to be competitive in the international arena. In this respect, NASA has initiated an innovative government/private sector program called the National Scholars Program (NSP) which I cited in my November 1989 report to the Congressionally mandated Task Force on Women, Minorities, and the Handicapped in Science and Technology.

The goal of NSP is to have all relevant Federal agencies and various private sector organizations fund a series of programs at the high school level through the graduate school level that would result in the production of more underrepresented minority science and engineering Ph.D's. NASA and the U.S. Department of Energy, through our Memorandum of Agreement, are getting the program started by folding into NSP many of our existing programs.

We are adding a new component to our highly successful Space Science Student Involvement Program (SSIP). Each year, over 1,000 junior high and high school students participate in a national competition by submitting proposed experiments that theoretically can be tested, for example, on a Space Station, in the wind tunnel at the NASA Langley Research Facility or the microgravity research facility at the NASA Lewis Research Center. The new component of the competition will involve research proposals for supercomputers and result in awarding Super Computer Internships at our Ames Research Center.

Another effort to influence the career paths of more students is our collaboration with the American Association for Counseling and Development (AACD). School guidance counselors

give students critical assistance in understanding the variety of careers available and in choosing the necessary courses to those career paths. Recently we convened an exploratory meeting with the AACD to look for ways to work together, including the development of new student materials concerning technical careers.

As we anticipate the increasing demands on our future science and engineering workforce, we have become even more sensitive to the important role of technicians, many of whom receive their education through community colleges. We have also come to appreciate that community colleges enroll a significant proportion of the nation's 12 million students in higher education, and that these institutions enroll approximately 40% of all minority students in higher education. Consequently, we have begun to examine ways in which our education programs, both external and internal, can work more closely with community colleges. We already have good experience with one model for this approach -- Kennedy Space Center's working relationship with Brevard Community College in Cocoa Beach, Florida.

Last year we carried out Phase I of the National Space Grant College and Fellowship Program. A major emphasis of this program is to provide both undergraduate and graduate fellowships to the 21 designated Space Grant Universities/Consortia with emphasis on recruiting women and underrepresented minorities. This new effort significantly increases NASA's existing fellowship programs to channel more students into the science and engineering pipeline.

Enhance the Knowledge Skills and Experience of Teachers and University Faculty

Reaching out to enhance, encourage and strengthen teacher skills is the third part of our strategy. It is a key element because it is where NASA has the best opportunity to leverage its resources and to ensure sustained change.

Recently we announced a new effort to infuse the theme of aeronautics and space into the training of teachers enrolled at colleges of education. Experience gained during this pilot program will provide us valuable information that may be useful to a broader set of colleges and universities in the future. The Learning About Science and Engineering Research (LASER) mobile teacher resource center was developed at the NASA Marshall Space Flight Center as a prototype NASA-industry partnership project. LASER brings NASA educational materials (e.g. teachers' guides, videotapes, software, slides, etc.) to those teachers not currently served by our existing teacher resource center network.

NASA is fortunate to have unique facilities to carry out its mission. NASA Select, our internal satellite video communications system, ties together all NASA Centers to provide communication in support of Space Shuttle missions and other NASA activities. While its primary purpose is mission support, this valuable resource can be used for education over extended periods. The footprint of our satellite system reaches all 50 states and is currently received by many cable TV systems as well as by those schools that have ground receiving stations. Soon, we will begin to utilize segments of the non-mission time on NASA Select for broadcasting existing educational and informational video tapes directly to teachers throughout our nation.

Our astronauts are seen as heroes and heroines by our nation's youth and their teachers. When visiting schools, astronauts can be excellent role models for children and adults alike as they relate their experiences and training. To use this resource strategically, I have created a new position for an educational specialist to work collaboratively with the Astronaut Corps at the NASA Johnson Space Center to seek out educational activities that enhance the training of teachers, capture student interest, and channel more students into the science and engineering pipeline.

One final example: we have begun work on defining a "Classroom of the Future." NASA, in its unique position at the forefront of many technology areas, is seeking to identify, define and develop a classroom that will take advantage of the latest technologies and learning strategies in using aerospace concepts in the teaching of science, math and technology. It is our intent to demonstrate this concept and to encourage its features be replicated by other classrooms around the country.

Conclusion

In closing, let me say that our nation must stop reacting to educational problems with short-term solutions. We must and can prepare long term strategies. Today, scientists and engineers comprise only 4% of American workers, but projections are that more will be needed in the future and it is obvious that their specialized and scarce skills are vital to our national welfare. Furthermore, all young people from kindergarten through high schools should also be exposed to mathematics, science and technology even if they do not pursue careers in these areas.

We have no choice but to provide this knowledge if we, as a nation, and our students, as citizens and job-holders, are to participate effectively in our world. I can assure you that NASA can be counted on to do our very best to help alleviate the national education crisis. We intend to be a reliable

partner in helping to implement the national education goals. We will continue to use our unique resources to conduct our aerospace education programs that capture student interest in science, mathematics and technology at an early age; channel more students into these career fields; and increase the knowledge, skills, and experiences of precollege teachers, college and university faculty and others.

Thank you.

EXCERPTS FROM REMARKS PREPARED FOR DELIVERY:

AT THE

DOWN TOWN ASSOCIATION
NEW YORK, NEW YORK

JUNE 8, 1990

RICHARD H. TRULY
NASA ADMINISTRATOR

THANK YOU.

I AM DELIGHTED TO BE HERE TODAY TO VISIT WITH YOU AT THE DOWN TOWN ASSOCIATION OF NEW YORK. I'M GLAD TO BE BACK AND SEE THAT NEW YORK IS FUNCTIONING NORMALLY; I'M CERTAIN THAT MY VISIT WON'T PUSH BUCKY DENT OR DAVEY JOHNSON OR DONALD TRUMP OFF THE FRONT PAGE! AND I'M SO PLEASED TO SEE MY DEAR FRIENDS, SECRETARY BILL ROGERS AND ZACHARY FISHER IN THE AUDIENCE TODAY.

IT IS ALWAYS A PLEASURE TO RETURN TO THIS MAGNIFICENT CITY WHICH IS IN SO MANY WAYS THE CROSSROADS OF THE WORLD. FRENCH PRESIDENT FRANCOIS MITTERAND COMMENTED THAT WHEN HE TRAVELS TO NEW YORK HE FEELS AS IF HE IS STEPPING INTO THE FUTURE. WELL, THE FUTURE IS PRECISELY WHAT I WOULD LIKE TO SPEAK WITH YOU ABOUT TODAY.

YOU CAN LOOK AT NEW YORK'S IMPRESSIVE SKYLINE AND GET A SENSE OF HOW FAR OUR SPACE PROGRAM HAS COME. THE ASTRONAUTS WHO WERE TREATED TO TICKER TAPE PARADES WENT TO THE MOON IN TINY CAPSULES. IN 1995, WE WILL BEGIN TO ASSEMBLE IN ORBIT INTERNATIONAL SPACE STATION FREEDOM THAT IS AS LONG AS THE UNITED NATION'S OFFICE BUILDING IS HIGH.

SPACE STATION FREEDOM WILL BE OUR FIRST PERMANENT HOME IN SPACE. THE NEXT WILL BE A BASE ON THE MOON FOR EXPLORATION AND SCIENTIFIC ACTIVITIES INCLUDING, IN ALL PROBABILITY, AN ARRAY OF RADIO AND OPTICAL TELESCOPES ON THE DARK SIDE WHICH WILL PROVIDE AN UNPRECEDENTED VIEW TO THE SOLAR SYSTEM. THE HUBBLE TELESCOPE SEES 10 TIMES CLEARER THAN THE BEST EARTH TELESCOPES. AN OPTICAL TELESCOPE ON THE MOON WOULD SEE WITH FAR GREATER CLARITY THAN HUBBLE.

OUR NATION -- INDEED MANKIND -- IS IN THE EARLY STAGES OF A PERIOD OF MANNED AND ROBOTIC SPACE EXPLORATION WHICH WILL RADICALLY CHANGE OUR UNDERSTANDING OF THE UNIVERSE. IT IS AMAZING HOW IGNORANT WE WERE ABOUT THE UNIVERSE, AND EVEN OUR SOLAR NEIGHBORHOOD, UNTIL WE LEARNED HOW TO ESCAPE EARTH'S GRAVITY 33 YEARS AGO. THIS PERMITTED US TO PLACE TELESCOPES ABOVE THE ATMOSPHERE AND LOOK AT RADIATION ACROSS THE SPECTRUM -- GAMMA RAYS, X-RAYS, INFRARED AND SO ON.

WE GAINED AN EXTRAORDINARY NEW LOOK AT THE UNIVERSE AND WHAT WE FOUND WAS NOTHING SHORT OF MIND BOGGLING. THE UNIVERSE TURNED OUT TO BE FAR LARGER THAN ANYONE THOUGHT, FAR MORE VIOLENT AND POPULATED BY BIZARRE OBJECTS LIKE QUASARS AND BLACK HOLES WHICH REMAIN PUZZLES.

THE ABILITY TO ESCAPE GRAVITY ALSO GAVE US THE OPPORTUNITY TO EXPLORE OUR TINY PATCH OF THE MILKY WAY GALAXY WITH ROBOT SPACECRAFT LIKE THE PIONEERS, MARINERS, VIKINGS AND VOYAGERS. THE MOST INTREPID SPACECRAFT WAS UNDOUBTEDLY VOYAGER II, WHICH COMPLETED ITS 12-YEAR TRIP TO THE GIANT OUTER PLANETS LAST AUGUST WITH A VISIT TO NEPTUNE, 2.8 BILLION MILES FROM EARTH. DURING ITS JOURNEY VOYAGER GAVE US CLOSE UP VIEWS OF JUPITER, SATURN, URANUS, AND NEPTUNE AND MANY OF THEIR MOONS. YESTERDAY, I HAD THE PRIVILEGE OF INTRODUCING THE VOYAGER TEAM TO PRESIDENT BUSH IN THE OVAL OFFICE AND LISTEN AS HE SALUTED THEIR PIONEERING ACHIEVEMENTS. THE VOYAGER SCIENTISTS PRESENTED THE PRESIDENT WITH A SPECTACULAR PHOTOGRAPH OF THE ENTIRE INNER SOLAR SYSTEM; ONE WHICH SHOWS OUR PLANET EARTH AS A TINY, SINGLE POINT OF LIGHT.

AMERICA'S REACH INTO SPACE HAS INDEED CHANGED OUR LIVES AND PRODUCED PRICELESS ECONOMIC, SOCIAL AND POLITICAL BENEFITS FOR MANKIND. PERHAPS THE PRIMARY REASON NO NUCLEAR WEAPON HAS BEEN USED IN ANGER SINCE WORLD WAR II IS BECAUSE SATELLITE SURVEILLANCE GIVES EAST AND WEST THE ABILITY TO MONITOR THE STRATEGIC FORCES OF THEIR OPPONENT AND PROVIDES RELIABLE AND RAPID EARLY WARNING OF ATTACK.

THE COMMUNICATIONS REVOLUTION MADE POSSIBLE BY SATELLITES -- INSTANTANEOUS, WORLDWIDE VOICE AND DATA COMMUNICATIONS -- HAS TRANSFORMED THE WAY WE WORK AND LIVE. WHEN NEIL ARMSTRONG STEPPED ONTO THE MOON IN 1969, HUNDREDS OF MILLIONS OF PEOPLE SHARED THE EXPERIENCE THROUGH THE LIVE, FLICKERING PICTURE FROM SPACE AND HAD THEIR FIRST TASTE OF THE TECHNOLOGY ADVANCES TO COME. OVER THE YEARS SINCE 1969, I HAVE TALKED TO SO MANY PEOPLE WHOSE MOST LASTING MEMORIES WERE THOSE BLACK AND WHITE TV IMAGES AND THE TWO SECOND DELAY IN COMMUNICATIONS – AN INDICATION OF VAST DISTANCES AND MARVELOUS THINGS TO COME.

TWENTY YEARS LATER, LAST YEAR ... THE REVOLUTION OF '89 SWEPT THE WORLD -- AND I THINK WE ARE ALL AWARE OF THE CRITICAL ROLE SATELLITE COMMUNICATIONS AND ADVANCED TECHNOLOGY PLAYED IN DIRECTLY ASSISTING HUNDREDS OF MILLIONS OF PEOPLE TO REALIZE THE FREEDOM WHICH ONLY A YEAR AGO SEEMED UNTHINKABLE.

NEXT IS WEATHER. WEATHER SATELLITES HAVE GREATLY IMPROVED OUR ABILITY TO FORECAST. CURRENT WEATHER SATELLITES WILL PALE IN COMPARISON TO THE ENVIRONMENTAL SATELLITES WHICH ARE COMING. IN A PROGRAM CALLED "MISSION TO PLANET EARTH," WE ARE GOING TO ORBIT SEVERAL GIANT PLATFORMS OF INSTRUMENTS TO EXAMINE THE INTERACTIVEGLOBAL SYSTEMS WE POPULARLY CALL THE ENVIRONMENT. WE MUST GET THE PRECISE DATA WE NEED TO PRESERVE THE CONDITIONS THAT ALLOW LIFE TO FLOURISH.

I HAVE SEEN THIS EARTH FROM SPACE, AND IT IS A PRECIOUS JEWEL. WE ARE REMARKABLY IGNORANT OF THE EFFECT OF INTERACTIONS BETWEEN THE LAND, THE SEA, THE ATMOSPHERE, AND THE ICE ... AND PARTICULARLY THE EFFECT THAT YOU AND I ARE HAVING. WE KNOW THAT THERE IS A TREND TOWARD GLOBAL WARMING. BUT IF WE MAKE AN UNINFORMED DECISION ON CURBING THE USE OF FOSSIL FUELS, A DISASTER COULD OCCUR. A BAD DECISION ONE WAY COULD WRECK THE ECONOMY; THE OTHER WAY ... THE ENVIRONMENT.

THE ONLY PLACE TO GET THE HARD DATA WE NEED IS FROM SPACE. IT OFFERS THE ONLY TOOL WE HAVE TO GATHER DATA SIMULTANEOUSLY ON A GLOBAL SCALE, WHICH SCIENTISTS, SUCH AS THOSE AT NASA'S GODDARD INSTITUTE FOR SPACE STUDIES, WHICH IS AFFILIATED WITH COLUMBIA UNIVERSITY AND LOCATED HERE IN MANHATTAN, WILL USE TO DEVELOP OUR FIRST TRUE UNDERSTANDING OF GLOBAL CHANGE.

ANOTHER OF THE BENEFITS OF SPACE EXPLORATION IS TECHNOLOGICAL SPINOFF. THROUGHOUT THE YEARS, TECHNOLOGIES INVENTED FOR SPACE HAVE BEEN TRANSLATED INTO SUCCESSFUL CONSUMER PRODUCTS AND PROCESSES BY PRIVATE ENTERPRISE ... PACEMAKERS AND LASER HEART SURGERY AND ADVANCED SEWAGE TREATMENT METHODS, TO NAME A FEW. SPACE HELPED GIVE AMERICA A WORLD LEAD IN COMPUTERS IT HAS NEVER SURRENDERED. THE NEED TO MAKE COMPONENTS SMALLER AND SMALLER FOR SPACE HELPED CREATE TODAY'S MAMMOTH INTERNATIONAL MICROELECTRONICS INDUSTRY. SO ALSO WITH ADVANCED MEDICAL EQUIPMENT.

THIS PROCESS OF TECHNOLOGY TRANSFER FROM SPACE TO PRIVATE CONSUMER APPLICATION HAS TAKEN PLACE SUCCESSFULLY IN THE PAST -- WE ARE DETERMINED TO MAKE IT WORK EVEN BETTER IN THE FUTURE.

THE SPACE EXPLORATION INITIATIVE .

THE NINETIES WILL BE A DECADE OF UNPARALLELED ADVANCE IN A BROAD SPECTRUM OF NEW SPACE ACHIEVEMENTS. LAST JULY 20 -- THE 20TH ANNIVERSARY OF THE MOON LANDING -- PRESIDENT BUSH SET TWO NATIONAL GOALS FOR AMERICANS TO ACHIEVE IN THE FIRST TWO DECADES OF THE NEXT AMERICAN CENTURY. THIS WILL BE A DISCOVERY PROGRAM OF THE FIRST ORDER, INVOLVING FIRST ROBOTIC EXPLORERS, FOLLOWED BY MEN AND WOMEN.

THE FIRST IS TO RETURN TO THE MOON -- THIS TIME TO STAY -- TO ESTABLISH A LUNAR RESEARCH BASE. THE SECOND IS FOR AMERICANS TO JOURNEY TO MARS BEFORE THE 50TH ANNIVERSARY OF THE APOLLO 11 LUNAR LANDING IN 2019.

THE WAY TO START ON OUR JOURNEYS INTO THE FUTURE IS TO INVENT THE NEW TECHNOLOGY REQUIRED --TECHNOLOGIES SUCH AS ADVANCED ROBOTICS, ARTIFICIAL INTELLIGENCE, VIRTUAL REALITY, HYPERSONIC FLIGHT, ARTIFICIAL SELF-SUSTAINING ECOLOGICAL SYSTEMS, AND LOW-COST SPACE TRANSPORTATION.

NASA HAS JUST BEGUN AN OUTREACH PROGRAM -- CALLING UPON THE BEST AND BRIGHTEST FROM INDUSTRY, ACADEMIA AND GOVERNMENT TO PRESENT NEW APPROACHES FOR EXPLORATION MISSIONS AND INNOVATIVE, HIGH LEVERAGE TECHNOLOGIES. WE WILL PROCEED WITH OUR FUTURE EXPLORATIONS IN AS WISE A MANNER AS IS POSSIBLE.

WE EXPECT YET ANOTHER SPINOFF FROM THE PRESIDENT'S SPACE EXPLORATION INITIATIVE -- I BELIEVE THE MOST IMPORTANT SPINOFF OF ALL BECAUSE IT HAS TO DO WITH KIDS. WE BELIEVE IT WILL INSPIRE OUR CHILDREN TO DO BETTER IN SCHOOL. WE ALL KNOW THAT EDUCATIONAL ACHIEVEMENT HAS DECLINED UNACCEPTABLY. NASA'S WORK -- THE SPACE PROGRAM CAN INSPIRE OUR CHILDREN TO ACHIEVE, ESPECIALLY IN MATHEMATICS AND SCIENCE.

IF YOU COMBINE AN EDUCATED POPULATION AND CUTTING EDGE TECHNOLOGY, YOU GET THE THIRD INGREDIENT FOR A HEALTHY AMERICAN ECONOMY -- THE ABILITY TO COMPETE SUCCESSFULLY IN THE WORLD MARKETPLACE.

INVESTING IN THE FUTURE

ALL THIS IS WHY PRESIDENT BUSH HAS ASKED CONGRESS TO INCREASE NASA'S BUDGET BY 23%. THIS IS THE LARGEST REQUESTED FOR ANY FEDERAL AGENCY AND WOULD PUT US JUST OVER THE $15 BILLION MARK.

THE PRESIDENT BELIEVES A STRONG SPACE PROGRAM CAN HELP TO RENEW AND STRENGTHEN THE FOUNDATIONS OF OUR ECONOMY AND WAY OF LIFE. IT IS IMPORTANT IN THIS TIME OF FISCAL CONSTRAINT THAT WE CONTINUE TO INVEST WISELY IN THE FUTURE -- BUILDING UPON THE NASA OF TODAY TO KEEP OUR NATION IN THE FOREFRONT OF AERONAUTICS AND SPACE TECHNOLOGY -- AND AMERICA HAS A STRONG, REINVIGORATED NASA TO BUILD UPON. WE HAVE OUR ACT TOGETHER.

NASA TODAY

SINCE WE RESUMED SPACE FLIGHT AFTER RECOVERING FROM CHALLENGER, WE HAVE FLOWN TEN HIGHLY PRODUCTIVE SAFE SPACE SHUTTLE MISSIONS AND FIVE EXPENDABLE ROCKET LAUNCHES. WE HAVE SENT MAGELLAN TO MAP VENUS, GALILEO TO PROBE THE ATMOSPHERE OF JUPITER, HUBBLE TO LOOK TO THE EDGE OF TIME, COBE TO EXAMINE THE REMNANTS OF THE BIG BANG, AND ROSAT TO DO A BROAD SURVEY OF X-RAY SOURCES.

WE SOON WILL BE SENDING ASTRO TO STUDY QUASARS AND COLLIDING GALAXIES, ULYSSES TO ORBIT THE SUN'S POLES FOR THE FIRST TIME, AND THE GAMMA RAY OBSERVATORY TO SEARCH FOR EVIDENCE OF NEUTRON STARS AND BLACK HOLES.

THE NASA AERONAUTICS RESEARCH PROGRAM, WHICH DATES TO 1915, IS ANOTHER STRENGTH. THANKS TO THIS RESEARCH, AMERICAN AVIATION PRODUCTS AND SERVICES STAND FIRST IN THE WORLD. THEY ARE THE BRIGHTEST SPOT IN OUR BALANCE OF PAYMENTS -- $19 BILLION IN THE BLACK. WE HAVE ALSO RESUMED RESEARCH ON A HYPERSONIC AIRCRAFT THAT WOULD TAKE OFF AND LAND CONVENTIONALLY, BUT ALSO FLY TO ORBIT.

ANOTHER PLUS IS NASA'S FULL-BORE COMMERCIAL DEVELOPMENT PROGRAM. WE NOW HAVE 16 CENTERS FOR THE COMMERCIAL DEVELOPMENT OF SPACE IN OPERATION. THEIR AFFILIATES INCLUDE 52 UNIVERSITIES AND 175 COMPANIES. WE ALSO HAVE STARTED A NEW SPACE GRANT COLLEGE PROGRAM INVOLVING 90 INSTITUTIONS.

MEANWHILE, EACH SPACE SHUTTLE MISSION CARRIES A NUMBER OF MATERIALS PROCESSING EXPERIMENTS SPONSORED BY COMPANIES AND UNIVERSITIES. MATERIALS COMBINE DIFFERENTLY IN THE ABSENCE OF GRAVITY, SO SCIENTISTS ARE LOOKING FOR ALLOYS MUCH LIGHTER, STRONGER AND HEAT RESISTANT THAN ANY WE HAVE TODAY. PHARMACEUTICAL FIRMS ARE SEARCHING FOR NEW DRUGS TO COMBAT DISEASES. SPACE STATION FREEDOM WILL HAVE LARGE, PERMANENTLY MANNED LABORATORIES TO EXPAND THIS WORK.

TO CONCLUDE, I WOULD LIKE TO MENTION A MORE FUNDAMENTAL REASON FOR ADVANCING AMERICA'S BOLD REACH INTO SPACE. MANY PEOPLE FIND IT DIFFICULT TO UNDERSTAND WHAT SPACE SCIENTISTS ARE SEEKING WHEN THEY FLY A SATELLITE AROUND A DISTANT PLANET TO EXAMINE ITS CHEMICAL MAKEUP, THE CHARACTERISTICS OF ITS ATMOSPHERE, THE FORCE OF ITS MAGNETIC FIELD AND SO ON. YOU ASK AND YOU FREQUENTLY GET AN INVOLVED TECHNICAL ANSWER.

THERE IS AN OVERARCHING REASON WE ALL CAN UNDERSTAND. THE ONLY PLACE THAT WE KNOW LIFE EXISTS IS EARTH. WE KNOW ABOUT THE COMPOSITION OF OUR LIFE-SUSTAINING ENVIRONMENT. SO, IN ADDITION TO ADVANCING TECHNOLOGY AND RESOURCES AND DISCOVERY, WE ARE EXPLORING THE GALAXY TO UNDERSTAND OTHER WORLDS, WITH THE HOPE OF GAINING INSIGHTS ABOUT OUR HOME PLANET.

AND THAT IS THE BOTTOM LINE FOR THE SPACE PROGRAM. PEOPLE WANT TO KNOW ABOUT THE UNIVERSE, ABOUT OTHER FORMS OF LIFE WHICH MIGHT BE OUT THERE, ABOUT THE PURPOSE OF HUMAN EXISTENCE AND THE DESTINY OF HUMANITY. FOLKS HAVE BEEN SEARCHING THE STARS FOR THOUSANDS OF YEARS SEEKING ANSWERS. WE STILL ARE. BUT NOW WE ARE NOT ANCHORED TO THE GROUND IN OUR QUEST.

THANK YOU.

EXCERPTS FROM REMARKS PREPARED FOR DELIVERY

TO THE

THE TOWN HALL OF CALIFORNIA
LOS ANGELES, CALIFORNIA

MARCH 7, 1990

RICHARD H. TRULY
NASA ADMINISTRATOR

ORIGINAL PAGE IS
OF POOR QUALITY

THANK YOU SAM (IACOBELLIS).

IT IS AN HONOR FOR ME TO ADDRESS TOWN HALL OF CALIFORNIA. FOR MORE THAN 50 YEARS YOU HAVE PROVIDED ONE OF THE ESSENTIALS OF A FREE, DEMOCRATIC SOCIETY - A FORUM FOR IDEAS AND POINTS OF VIEW. AND THAT'S GREAT, SINCE CALIFORNIA IS KNOWN TO HAVE PLENTY OF BOTH!

THE INFLUENTIAL FORUM YOU PROVIDE ... AND ITS CRUCIAL LOCATION IN A STATE WHICH SERVES IN SO MANY WAYS AS AMERICA'S BRIDGE TO THE PACIFIC RIM ... MAKES THIS A MOST IMPORTANT PODIUM FOR ANY SPEAKER ... BUT PARTICULARLY FOR THE ADMINISTRATOR OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION. NASA HAS A LARGE PRESENCE IN CALIFORNIA ... ONE WHICH DATES TO THE INCEPTION OF OUR AGENCY. STRONG LINKS EXIST BETWEEN YOU AND NASA, AS WE CONTINUE TO WORK TOGETHER ON A WIDE RANGE OF PROGRAMS ON THE CUTTING EDGE OF SCIENCE AND TECHNOLOGY.

NASA HAS THREE MAJOR FACILITIES HERE:

o ONE IS THE JET PROPULSION LABORATORY, A FEW MILES AWAY IN LA CANADA. A MARVELOUS GROUP OF PEOPLE THERE DESIGN, BUILD, AND DISPATCH OUR ROBOT EXPLORERS THROUGHOUT THE SOLAR SYSTEM.

o ANOTHER IS THE AMES RESEARCH CENTER IN MOUNTAIN VIEW, WHOSE PEOPLE SEEM LIKE RENAISSANCE MEN AND WOMEN, EXPERT IN A MULTITUDE OF RESEARCH AREAS - LIFE SCIENCES; SPACECRAFT DESIGN; CUTTING-EDGE AERONAUTICS; AND NEW, EXOTIC TECHNOLOGIES LIKE ARTIFICIAL INTELLIGENCE AND VIRTUAL REALITY.

o OUR THIRD FACILITY IS THE DRYDEN FLIGHT RESEARCH FACILITY LOCATED ON THE EDWARDS DRY LAKE BED. THERE THE MOST ADVANCED IDEAS IN FLIGHT GET THEIR FIRST REAL TEST AT THE HANDS OF NASA RESEARCH PILOTS, AND THAT'S WHERE THE SPACE SHUTTLES COME HOME TO ROOST, JUST AS ATLANTIS DID THIS PAST WEEKEND.

IN ALL, NASA EMPLOYS 9,730 PEOPLE AT THESE THREE CENTERS. ADD THE CALIFORNIA CONTRACTORS WORKING ON NASA PROJECTS, AND YOU HAVE A TOTAL OF 70,332 NASA-RELATED JOBS IN THIS STATE! OUR SPENDING HERE IN FISCAL 1990 WILL BE ALMOST $3.8 BILLION ... ONE-THIRD OF ALL NASA PROCUREMENT.

AS YOU CAN SEE, C[illegible]RTUNES WILL BE YOUR FORTUNES. AND I AM HERE TO TELL YOU THAT [illegible]OLLECTIVE FUTURE LOOKS BRIGHT.

TODAY'S NASA

TODAY, AMERICA'S SPACE PROGRAM IS IN EXCEPTIONALLY GOOD SHAPE. IN FACT, 1989 WAS ONE OF OUR BEST YEARS IN SPACE. SINCE OUR RETURN TO FLIGHT AFTER CHALLENGER, WE HAVE COMPLETED NINE SUPERBLY SUCCESSFUL SPACE SHUTTLE MISSIONS, AND EIGHT CONSECUTIVE MIXED FLEET EXPENDABLE VEHICLE LAUNCHES HAVE DELIVERED THE GOODS. THESE MISSIONS HAVE STARTED AN ERA THAT THE WORLD WILL REMEMBER AS A GOLDEN AGE OF SPACE SCIENCE.

FOLLOWING DEPLOYMENT FROM ATLANTIS LAST MAY,

o MAGELLAN IS TRAVELING ON HER JOURNEY TO LOOK THROUGH THE THICK SULFURIC CLOUDS OF VENUS AND MAKE A RADAR MAP OF ITS SURFACE.

o AND GALILEO, THE MOST SOPHISTICATED ROBOTIC SPACECRAFT EVER BUILT, BEGAN HER JOURNEY LAST OCTOBER ... ALSO FROM ATLANTIS ...TO ORBIT JUPITER AND DROP A PROBE INTO ITS VIOLENT ATMOSPHERE. WE EXPECT TO FIND PRIMORDIAL MATERIAL WHICH WILL HELP DETERMINE THE VERY ORIGINS OF OUR SOLAR SYSTEM.

o IN NOVEMBER, A DELTA ROCKET CARRIED THE COSMIC BACKGROUND EXPLORER INTO ORBIT TO STUDY REMNANTS OF THE BIG BANG THAT CREATED THE UNIVERSE AND TO LOOK BACK AT THOSE VERY FIRST FEW MOMENTS OF OUR EXISTENCE.

o SURELY, THE EYES OF THE WORLD WERE ON THE JET PROPULSION LABORATORY WHEN A TEAM OF SCIENTISTS, ENGINEERS, AND TECHNICIANS CULMINATED 12 YEARS OF INNOVATION AND INGENUITY BY PUTTING VOYAGER 2 PRECISELY ON TARGET TO VISIT THE PLANET NEPTUNE – 2.3 BILLION MILES FROM EARTH! I CALL VOYAGER "THE LITTLE SPACECRAFT THAT COULD" ... SHE TOOK US ON A THRILLING EXPLORATION OF ALL THE GIANT PLANETS.

AND LAST YEAR WAS ONLY A WARM UP! NEXT MONTH, DISCOVERY WILL DEPLOY THE FIRST OF OUR FOUR SPACE-BASED GREAT OBSERVATORIES, THE HUBBLE SPACE TELESCOPE. THROUGH HUBBLE'S EYES, WE WILL PEER BACK, VIRTUALLY TO THE BEGINNING OF TIME, WITH UNPRECEDENTED CLARITY.

o IN MAY, COLUMBIA ASTRONAUTS WILL SURVEY THE SKY WITH AN ADVANCED X-RAY TELESCOPE TO GET PRECISE INFORMATION ABOUT MATERIALS CREATED WHEN A SUPERNOVA EXPLODES, PLUS KNOWLEDGE ABOUT THE NATURE OF QUASARS AND VERY HOT STARS.

THE LIST GOES ON

o IN AUGUST, A SPACELAB LIFE SCIENCES MISSION WILL STUDY THE EFFECTS OF WEIGHTLESSNESS ON THE HUMAN BODY.

o IN OCTOBER, THE ULYSSES SPACECRAFT WILL STUDY THE POLAR REGIONS OF THE SUN ... FOR THE FIRST TIME IN HISTORY.

o IN NOVEMBER, THE SECOND GREAT OBSERVATORY -- THE GAMMA RAY OBSERVATORY – WILL LOOK AT THE HOTTEST EMISSIONS IN THE SKY – THE PRODUCTS OF NEUTRON STARS, BLACK HOLES AND COLLIDING GALAXIES.

ALL TOLD, 36 EXTRAORDINARY SPACE SCIENCE MISSIONS IN A 5-YEAR PERIOD! WHEN WE ARE DONE, THIS ERA OF SCIENTIFIC EXPLORATION WILL HAVE RADICALLY CHANGED OUR UNDERSTANDING OF THE UNIVERSE ... AND OURSELVES.

CONCENTRATING ON EARTH

I HAVE TALKED ABOUT LOOKING OUTWARD INTO THE SOLAR SYSTEM AND THE UNIVERSE BEYOND. THIS YEAR, PRESIDENT BUSH HAS ASKED CONGRESS TO ALLOW US TO LOOK INWARD -- BACK AT OUR OWN, PRECIOUS EARTH – TO ALLOW US FOR THE FIRST TIME TO UNDERSTAND HOW THE PLANET WORKS AS AN INTERACTIVE SYSTEM THAT ALLOWS LIFE TO FLOURISH. ACCURATE INFORMATION WILL ALLOW DECISION MAKERS TO DETERMINE HOW TO BEST PROTECT THIS GLOBAL ENVIRONMENT AND BALANCE ACTIONS TAKEN AGAINST ECONOMIC AND POLITICAL CONSIDERATIONS.

I HATE TO TELL YOU THIS ... BUT THE EARTH IS IN TROUBLE ... AND WE -- YOU AND I – ARE THE CULPRITS. WE ARE BURNING THE FORESTS OF THE WORLD AT A RATE OF ONE STATE OF TENNESSEE A YEAR. IN FACT, WE DUMP MORE THAN FIVE BILLION METRIC TONS OF CARBON IN THE FORM OF CARBON DIOXIDE INTO THE ATMOSPHERE EACH YEAR ... MORE THAN ONE TON A YEAR FOR EVERY MAN, WOMAN, AND CHILD ON EARTH. EVENTUALLY, SOME VERY TOUGH DECISIONS NEED TO BE MADE. FOR EXAMPLE, HOW MUCH SHOULD WE CURB USE OF FOSSIL FUEL? A BAD ANSWER ONE WAY RUINS THE ENVIRONMENT; A BAD ANSWER THE OTHER WAY RUINS THE ECONOMY.

OUR EARTH IS THE MOST COMPLICATED PLANET IN THE SOLAR SYSTEM, WITH INTERACTIONS AMONG THE ATMOSPHERE, THE OCEANS, AND LIFE. AND WE ARE REMARKABLY IGNORANT OF HOW IT ALL WORKS. BUT WE ARE NOT IGNORANT OF WHAT WE NEED TO DO TO OBSERVE AND UNDERSTAND THE EARTH.

HARD QUESTIONS NEED ANSWERS BASED ON HARD DATA. THE WORLD DOES NOT HAVE ADEQUATE ENVIRONMENTAL DATA NOW. AND THE ONLY PLACE IT CAN GET IT IS FROM SPACE. SPACE OFFERS THE ONLY TRUE GLOBAL PERSPECTIVE OF OUR ENVIRONMENTAL SYSTEM, WITH ALL ITS CONSTITUENT PARTS. SPACE GIVES THE WORLD ITS BEST OPPORTUNITY TO UNDERSTAND HOW TO PRESERVE THE BEAUTY AND BOUNTY OF OUR SMALL PLANET FOR ALL GENERATIONS TO COME.

NASA'S ROLE IN GLOBAL CHANGE IS WHAT WE CALL "MISSION TO PLANET EARTH." OF COURSE, NASA HAS BEEN BUILDING EARTH OBSERVING SATELLITES FOR YEARS. WHAT I AM TALKING ABOUT HERE IS AN EFFORT OF SUCH MAGNITUDE THAT IT DWARFS EVERYTHING IN THE PAST ... A WORLDWIDE EFFORT EMBRACING MANY COUNTRIES. NUMEROUS SATELLITES WILL STUDY THE COMPLEX INTERACTIONS BETWEEN THE LAND, THE SEA, THE ICE AND THE ATMOSPHERE, AS WELL AS BETWEEN THE EARTH AND THE SUN.

THE EARTH OBSERVING SYSTEM ... THE CENTERPIECE OF "MISSION TO PLANET EARTH" ... IS ONE MAJOR COMPONENT OF A BALANCED, FORWARD-LOOKING FISCAL 1991 BUDGET REQUEST FOR NASA WHICH PRESIDENT BUSH PRESENTED TO CONGRESS ON JANUARY 29.

THAT BUDGET REQUESTS $15.1 BILLION FOR NASA ... A 23% INCREASE OVER FISCAL 1990 AND ... THE LARGEST PERCENTAGE INCREASE FOR ANY FEDERAL AGENCY. BUT I COULD HAVE TOLD YOU LAST YEAR THAT THIS HAD TO BE ABOUT THE FUNDING LEVEL FOR NASA ... BECAUSE FULLY 98% OF THIS REQUEST GOES TO PROGRAMS ALREADY APPROVED AND APPROPRIATED BY CONGRESS!

AMERICA'S ROLE IN AN UNCERTAIN WORLD

THIS BUDGET HAS BEEN PROPOSED AT A TIME OF UNBELIEVABLE ... AND EXHILARATING ... WORLD CHANGE. I CAN ASSURE YOU THAT NASA IS NOT ISOLATED AND OPERATING IN ITS OWN LITTLE WORLD. WE ARE KEENLY AWARE OF EVENTS SWEEPING THE SOVIET UNION, THE TWO GERMANIES, CZECHOSLOVAKIA, ROMANIA, HUNGARY, POLAND, BULGARIA, THE REPUBLIC OF SOUTH AFRICA, PANAMA, AND NICARAGUA. PEOPLE ARE DEMANDING AND GETTING DEMOCRATIC GOVERNMENTS AND NEW ECONOMIC SYSTEMS.

HERE AT HOME, AMERICANS HAVE LITTLE TIME TO CHEER THESE VICTORIES OF DEMOCRACY AS THEY STRUGGLE WITH PROBLEMS AND PONDER PRIORITIES IN AREAS LIKE THE FEDERAL DEFICIT, SCHOOLS, ENVIRONMENT, DRUGS, STREET CRIME, HOUSING, AND HEALTH.

UNCERTAINTY ABOUNDS BOTH OVERSEAS AND AT HOME, INCLUDING QUESTIONS ABOUT THE ROLE OF THE UNITED STATES IN THIS CHANGING WORLD. HOWEVER, ONE THING IS CERTAIN .. THAT PEOPLE IN CHANGING NATIONS ARE LOOKING TO THE UNITED STATES ... FOR LEADERSHIP.

INVESTING IN AMERICA'S FUTURE

WHY THEN, AT A TIME OF SUCH INTERNATIONAL UNCERTAINTY AND NATIONAL STRAIN, HAS THE PRESIDENT COMMITTED TO A BUDGETARY INCREASE OF SUCH MAGNITUDE FOR NASA? THE OBVIOUS ANSWER IS THAT HE, LIKE THE MAJORITY OF AMERICANS, FAVORS A STRONG SPACE PROGRAM. BUT THE PRESIDENT'S REASONS GO FAR BEYOND THAT.

HE ALSO DID IT BECAUSE OF CONCERN HE SHARES WITH ALL AMERICANS ABOUT THE VERY PILLARS OF THE AMERICAN ECONOMY AND WAY OF LIFE THAT PROVIDE THE WHEREWITHAL TO SOLVE THE PROBLEMS:

- FIRST AND FOREMOST, OUR EDUCATIONAL SYSTEM.

- OUR ABILITY TO REGAIN AND RETAIN WORLD TECHNOLOGICAL LEADERSHIP.

- AND OUR ABILITY TO COMPETE SUCCESSFULLY IN THE WORLD MARKETPLACE.

THERE IS NO NEED FOR ME TO REPEAT THE DREARY LITANY OF TROUBLE IN THESE INTERWOVEN AREAS. WE ARE ALL KEENLY AWARE OF THE DECLINE OF EDUCATIONAL ACHIEVEMENT, ESPECIALLY IN MATHEMATICS AND SCIENCE, OF GROWING TECHNOLOGICAL PROWESS IN OTHER COUNTRIES, AND OF THE DECLINING POPULARITY OF VARIOUS AMERICAN GOODS AND SERVICES IN WORLD MARKETS. WHAT I WANT TO TALK ABOUT IS THE RESPONSE TO THESE CHALLENGES.

PRESIDENT BUSH CLEARLY KNOWS WHERE TO LOOK FOR SOLUTIONS. HE IS COMMITTED TO A STRONG, CONTINUING INVESTMENT IN AMERICA'S FUTURE. THAT IS WHY HE BOOSTED SCIENCE AND TECHNOLOGY IN SEVERAL MAJOR AREAS ... AND GAVE NASA ITS HEALTHY AND MOST NECESSARY INCREASE. NASA'S BUDGET IS FOCUSED UPON PROVIDING SOLUTIONS TO THE PROBLEMS WE FACE IN INNOVATION, EDUCATION, AND COMPETITIVENESS.

AND WITH THIS SUPPORT:

- NASA WILL MOVE BEYOND BASELINE PLANNING AND BEGIN ACTUAL FABRICATION OF SPACE STATION FREEDOM.

- WE WILL PRESS AHEAD, WITH INNOVATIVE PRIVATE INVESTMENT ARRANGEMENTS IN SPACE FLIGHT SUCH AS THE ONE TO BE UNDERTAKEN WITH ROCKWELL, RIGHT HERE IN LOS ANGELES, TO DEVELOP AN EXTENDED DURATION SPACE SHUTTLE ... AND WE WILL ALSO DEVELOP NEW ROCKETS TO BOOST HEAVIER PAYLOADS.

- WE WILL CONTINUE OUR LEGACY IN DEVELOPMENT OF CUTTING-EDGE AERONAUTICS RESEARCH ... LET'S NOT FORGET THAT THE FIRST "A" IN NASA STANDS FOR AERONAUTICS.

- AND WE WILL START DEVELOPMENT OF THE NEW TECHNOLOGIES REQUIRED FOR A SUSTAINED AND CONTINUING EXPLORATION OF THE SOLAR SYSTEM BY BOTH HUMANS AND ROBOTS.

IF THE PAST INDEED IS PROLOGUE, AMERICAN INDUSTRY WILL TRANSFORM THE NEW AERONAUTICS, SPACE, AND RELATED TECHNOLOGIES -- THAT EMERGE FROM OUR PROGRAMS -- INTO PRODUCTS AND PROCESSES THAT WILL CAPTURE WORLD MARKETS. IT HAS HAPPENED IN THE PAST; IT CAN HAPPEN AGAIN.

PRESIDENT BUSH IS WELL AWARE OF THAT, AND HIS MARCHING ORDERS ARE FOR US TO BE LEADERS ONCE MORE.

SPACE STATION FREEDOM

AN ABSOLUTELY ESSENTIAL PART OF OUR SPACE PROGRAM -- THE KEY TO PROGRESS -- IS SPACE STATION FREEDOM.

FREEDOM WILL BE A PERMANENT, LARGE, HANDS-ON LABORATORY FOR MATERIALS AND LIFE SCIENCES RESEARCH IN ORBIT. LATER, IT ALSO WILL BECOME THE ASSEMBLY POINT FOR THE SHIPS THAT GO TO THE MOON AND MARS AND THE LABORATORIES TO EXAMINE THE THINGS THEY BRING BACK AS WE LOOK FOR RESOURCES AND EVIDENCE OF LIFE.

SCIENTISTS ABOARD THE STATION WILL DEVELOP MATERIALS THAT ARE LIGHTER, STRONGER, AND MORE HEAT RESISTANT THAN ANY WE KNOW TODAY. PEOPLE HERE ON EARTH WILL BE THE BENEFICIARIES OF NEW PHARMACEUTICAL PRODUCTS THAT WILL BE DEVELOPED THERE.

AND SPACE STATION FREEDOM IS ABOUT DISCOVERY:

ON THE DAY THAT BENJAMIN FRANKLIN FLEW HIS KITE IN A THUNDERSTORM, DID HE FORESEE CITIES LIT WITH ELECTRIC LIGHTS, STUDENTS AND SCIENTISTS USING COMPUTERS, AND ALL THE REST? OF COURSE NOT. BUT THE ELEMENTS OF DISCOVERY WERE IN HIS HANDS, AS THEY WILL BE IN THE HANDS OF SPACE STATION FREEDOM ASTRONAUTS.

AND SPEAKING OF DISCOVERY, NOTHING NASA HAS DONE HAS SO BENEFITED THE NATION ECONOMICALLY AS OUR DISCOVERY AND RESEARCH IN CUTTING-EDGE AERONAUTICS, AND IT'S STILL GOING ON.

AERONAUTICS RESEARCH

THIS RESEARCH HAS ENABLED THE U.S. AEROSPACE INDUSTRY TO MAINTAIN AN UNQUALIFIED LEAD IN WORLD MARKETS. AEROSPACE INDUSTRY SALES REMAIN THE BRIGHTEST SPOT IN OUR BALANCE OF TRADE ... $19 BILLION IN BLACK INK.

PLENTY OF NEW TECHNOLOGY WILL EMERGE FROM THE JOINT NASA/DOD NATIONAL AERO-SPACE PLANE. WHAT IS IT? IT IS A PLANE THAT WILL TAKE OFF LIKE A CONVENTIONAL AIRCRAFT, FLY INTO EARTH ORBIT, AND RETURN LIKE AN AIRLINER. ITS ENGINE WILL NOT BE EASY TO PERFECT BUT WILL BE EXTRAORDINARY WHEN COMPLETED.

ANOTHER OPPORTUNITY FOR UNITED STATES COMPETITIVENESS IS RISING RAPIDLY ON THE NASA AERONAUTICS AGENDA. RECENT STUDIES CONSISTENTLY INDICATE A LARGE, VIABLE COMMERCIAL MARKET EMERGING AROUND THE PACIFIC RIM FOR A FAST, SUPERSONIC CIVIL TRANSPORT. DO YOU REMEMBER WHEN THIS NATION TERMINATED DEVELOPMENT OF A SUPERSONIC TRANSPORT ALMOST 20 YEARS AGO BECAUSE OF ENVIRONMENTAL CONCERNS? WE BELIEVE THAT NASA RESEARCH CAN LICK THOSE CONCERNS NOW -- THAT IS, PREVENT DAMAGE TO THE OZONE LAYER AND CONTROL SONIC BOOM NOISE. SO WE ARE RETURNING TO THAT RESEARCH.

IT IS A LONG WAY FROM THE PACIFIC RIM TO THE MOON AND MARS, BUT THE 21ST CENTURY WILL SEE HUMAN EXPLORERS IN BOTH PLACES.

EXPLORATION AND THE 21ST CENTURY

IN THE 1991 BUDGET, PRESIDENT BUSH HAS PROPOSED THAT WE BEGIN WORK TOWARD THE CENTURIES-OLD DREAM OF EXTENDING THE HUMAN PRESENCE TO OTHER BODIES IN SPACE. THE DREAM BECAME NATIONAL POLICY LAST JULY 20, THE 20TH ANNIVERSARY OF THE APOLLO LANDING ON THE MOON. SPEAKING IN WASHINGTON, THE PRESIDENT DELIVERED THESE WORDS WHICH I BELIEVE WILL STAND THE TEST OF TIME:

> "I AM PROPOSING A LONG-RANGE, CONTINUING COMMITMENT. FIRST, FOR THE COMING DECADE ... FOR THE 1990'S ... SPACE STATION FREEDOM ... OUR CRITICAL NEXT STEP IN ALL OUR SPACE ENDEAVORS.
>
> AND NEXT ... FOR THE NEW CENTURY ... BACK TO THE MOON. BACK TO THE FUTURE. AND THIS TIME, BACK TO STAY.
>
> AND THEN ... A JOURNEY INTO TOMORROW ... A JOURNEY TO ANOTHER PLANET ... A MANNED MISSION TO MARS."

HOW DO WE START? WE BEGIN BY DEVELOPING THE NEW TECHNOLOGIES AND SEARCHING FOR THE NEW KNOWLEDGE THAT MUST BE ACQUIRED. THE 1991 BUDGET CONTAINS MONEY TO GET STARTED.

WHEN YOU LOOK AT ALL THESE MATTERS -- SCIENCE, AERONAUTICS, AND DISCOVERY TECHNOLOGY -- AND DIVIDE THEM INTO THEIR COMPONENT PARTS, THE RELATIONSHIP BETWEEN NASA AND AMERICA'S TECHNOLOGICAL LEADERSHIP AND COMPETITIVENESS BECOMES READILY APPARENT.

WE ARE TALKING ABOUT SUCH CUTTING-EDGE TECHNOLOGIES AS ADVANCED ROBOTICS, ARTIFICIAL INTELLIGENCE, SUPERCOMPUTERS, WIRELESS POWER TRANSMISSION, ULTRA HIGH STRENGTH AND HIGH TEMPERATURE RESISTANT MATERIALS ... THE LIST GOES ON AND ON.

WE WORK ON THESE TECHNOLOGIES IN THE SPACE PROGRAM. JUST IMAGINE WHAT AMERICAN PRIVATE ENTERPRISE WILL BE ABLE TO DO WITH THEM!

EDUCATION IS THE KEY

I HAVE MENTIONED EDUCATION SEVERAL TIMES TODAY AND WISH TO TOUCH ON IT AGAIN BECAUSE IT IS SO IMPORTANT. LAST WEEK, I WAS AT THE WHITE HOUSE WITH THE PRESIDENT AND THE GOVERNORS – INCLUDING GOVERNOR DEUKMEJIAN – DISCUSSING NATIONAL EDUCATION GOALS.

NASA IS RESOLVED TO SUPPORT THOSE AMBITIOUS GOALS BY PUTTING INTO EFFECT EVERY GOOD IDEA WE CAN TO USE THE SPACE PROGRAM TO ENCOURAGE STUDENTS IN AMERICAN GRAMMAR AND HIGH SCHOOLS AND COLLEGES AND UNIVERSITIES TO DO BETTER – TO BECOME WORLD CLASS AGAIN.

NASA ALWAYS HAS SUPPORTED A STRONG EDUCATIONAL PROGRAM, USING THE INSTINCTIVE INTEREST OF CHILDREN IN AIRPLANES, SPACESHIPS, ASTRONAUTS, AND EXPLORATION TO DRAW THEM INTO MATH AND SCIENCE DISCIPLINES.

SO IF YOUR TEENAGER COMES HOME WITH A GEOMETRY PROBLEM INVOLVING THE MOVEMENT OF PLANETS, OR AN ALGEBRA PROBLEM INVOLVING THROW WEIGHTS AND FUEL CONSUMPTION, OR A STATISTICS PROBLEM ABOUT THE POSSIBILITIES OF INTELLIGENT LIFE ELSEWHERE IN THE UNIVERSE, DON'T BE SURPRISED.

SUMMING UP

I WISH TO CONCLUDE WITH AN ASSUMPTION. IT IS THAT CALIFORNIANS KNOW ABOUT SPACE AND AERONAUTICS AND SCIENCE ... THAT YOU BELIEVE IN INVESTMENT IN THE FUTURE ... THAT YOU UNDERSTAND THE CONNECTION BETWEEN TECHNOLOGY AND COMPETITIVENESS AND ECONOMIC STRENGTH ... AND THAT YOU APPRECIATE THAT INVESTMENT IN THE NATION'S AERONAUTICS AND CIVIL SPACE PROGRAM IS AN INVESTMENT IN THIS NATION'S LONG-TERM ECONOMIC AND SOCIAL VIABILITY.

IF YOU FIT THAT DESCRIPTION, THEN I THINK YOU SHARE WITH PRESIDENT BUSH, AND ME, AND OTHERS CONCERNED ABOUT THE COURSE OF OUR COUNTRY, A RESPONSIBILITY FOR THE FUTURE OF THE NATION'S SPACE AND AERONAUTICS PROGRAM.

THE PRESIDENT'S VOTE OF CONFIDENCE IN NASA IS, IN FACT, A MESSAGE ABOUT THE SPACE PROGRAM, AND ITS FEEDBACK INTO OUR ECONOMY, THAT YOU AND I COLLECTIVELY MUST GET ACROSS TO PEOPLE WHO HAVE NOT HEARD IT. THE MESSAGE INVOLVES ALL THAT WE HAVE CONSIDERED HERE TODAY AND MIGHT BE SUMMARIZED LIKE THIS:

- NASA HAS ITS ACT TOGETHER.
- THE CURRENT CIVIL SPACE PROGRAM IS THE BEST IN HISTORY.
- THE WORLD IS LOOKING FOR LEADERSHIP.
- LEADERSHIP IS SEIZING BOLD OPPORTUNITIES – ESPECIALLY IN UNCERTAIN TIMES – AND INVESTING IN THE FUTURE.
- THE BUDGET THAT THE PRESIDENT HAS PUT ON THE TABLE IS THE BEST BALANCED BUDGET NASA HAS EVER HAD AND CONTAINS THE KIND OF AGGRESSIVENESS THE NATION NEEDS TO MAKE THIS PROGRAM WORK FOR EVERYONE'S GOOD...THE WORLD'S GOOD, IN FACT.

GETTING ACROSS THAT MESSAGE WILL BE A GREAT CHALLENGE. BUT THE OPPORTUNITY IT REPRESENTS ALSO IS GREAT – AS A MATTER OF FACT, I BELIEVE IT IS UNPRECEDENTED.

THANK YOU.

NASA

THE SPACE EXPLORATION INITIATIVE

A Speech at the Annual Meeting
American Institute of Aeronautics and Astronautics

May 1, 1990

Arnold D. Aldrich
Associate Administrator
Office of Aeronautics,
Exploration and Technology

I am delighted to be here this afternoon. AIAA's annual meeting is a great opportunity to see old friends and to talk with colleagues in the aerospace industry. We have a common commitment to the space program which demands the best from all of us in industry and in government.

I'm also glad to be here, because it gives me an opportunity to leave with you some messages, which I feel very strongly about.

For many years, throughout the 1970's and the early 1980's, NASA was frequently criticized for lacking vision, for having no strategic plan, for not really knowing where it was going.

To those of us in aerospace, working on the Space Shuttle or TDRSS or on HEAO or on any of the other splendid programs of the last 15 years, this kind of commentary did not ring true.

Intuitively, I think we knew where we were going. We knew it was America's destiny to move out again from low Earth orbit and to explore the solar system with both manned and unmanned vehicles. We knew that Apollo was but a first step on a long, inevitable journey. And we knew that the projects we were working on were laying a foundation for another moment in history when men, and this time women as well, would break loose from Earth, head back to the Moon and ultimately out into the solar system.

I believe we knew, although we had no focus to explain, that our work fit into a larger purpose, one that combined the human imperative to explore with an American desire to lead the way.

What we didn't have was a political commitment to do what all of us knew was eventually going to need to be done. We didn't have a statement of national policy that provided a framework in which to understand and structure the future space program. We didn't have a timetable. And we didn't have the analysis and penetrating studies which must precede great public ventures.

Well, ladies and gentlemen, I believe we have all of these now.

(First Chart)

In 1986, Dr. Tom Paine and his commission laid out an assessment of space activity in the 21st century that offers us a vision of greatness built upon specific programs.

In 1987, Dr. Sally Ride gave us a thoughtful look at space leadership, and outlined a future set of activities that would enable the United States to retain its preeminent position among spacefaring nations.

As the first head of the Office of Exploration, John Aaron took an engineer's look at possible pathways to the Moon and Mars. His report, Beyond Earth's Boundaries, provided a sound basis for further, more intense, analysis which was conducted at the Johnson Space Center during a 90-day period last year.

These are three outstanding pieces of work. I found them well worth rereading, and I suspect you would too.

And now we have a national space policy. Here is a document that deserves more attention and credit than it receives. The policy statement sets forth clearly, and I think very sensibly, a set of national goals and objectives, as well as guidelines and implementing actions. The policy document revalidates the on-going direction of U.S. space efforts and provides a framework to guide future activities.

As you read the space policy, note the last national goal, goal number six. It specifies that an overall goal of the United States is "to expand human presence and activity beyond Earth orbit into the solar system."

In this room, we may all be dreamers, but the dream is now incorporated in the official policy of the United States government.

And lastly, we have a political commitment. Last July, an extraordinary speech was given. The words spoken crystalized the feelings we all had about space exploration as we worked on various programs in earlier years. These words gave political legitimacy to our dreams.

(Next Chart)

"In 1961, it took a crisis--the space race--
to speed things up. Today we do not
have a crisis. We have an opportunity.
To seize this opportunity, I am not proposing
a 10-year plan like Apollo. I am proposing
a long-range, continuing commitment.
First, for the coming decade--for the 1990's--Space Station
Freedom--our critical next step in all our space endeavors.
And next--for the new century--back to the Moon. Back to the
future. And this time,
back to stay. And then a journey into tomorrow--a journey to
another planet--
a manned mission to Mars."

As you know, these words were not spoken by Admiral Truly nor by the CEO of one of the companies represented in this room, and certainly not by me. They were spoken by the Chief Executive Officer of our nation's federal government.

And President Bush didn't stop there. Two months ago, in a speech at the University of Tennessee, the President restated the goal of placing Americans on Mars and said we would do so within the lifetime of the scientists and engineers recruited for the job.

I interpret the President's remarks as a timetable. A general timetable, perhaps, but a timetable nonetheless. We <u>will</u> complete Space Station Freedom in the 1990's, return to the Moon in the first decade of the new century, and journey on to Mars in the decade following.

(Chart Down)

The President has outlined our course of action. He has said this is what we are going to do.

Admiral Truly will be making recommendations to the President about how to proceed. In order to accomplish this, he and NASA are working closely with the Vice President to make sure President Bush has realistic, yet imaginative, options to consider.

Our job, yours and mine, is to define how best to technically carry out these expeditions. Along with experts from the Department of Energy and the Department of Defense, NASA will lay out the program possibilities for deliberation by Vice President Quayle and the Space Council.

One of my jobs is to support the National Space Council and to work closely with Mark Albrecht. My office of Aeronautics, Exploration and Technology is doing so to the best of our ability.

The Space Council provides a much needed focus for space issues within the government. It is providing guidance and leadership for SEI as it did last summer for the NASP Program and I, for one, am very pleased that it is playing a major role in the decision making process.

Decision making in Washington is a very unusual process. In my five years here in the nation's capital, I have watched the process up close and found it <pause> most interesting.

One dimension of decision making, though, has truly fascinated me. And that is the importance of clearly conveying, time and time again, why you want to do something. "Why" is the most important public policy question there is, and as I travel through the decision checkpoints of our government (and there are many of them), I find myself having to return to basics and to lay out the rationale for what NASA seeks to accomplish.

To be succesful, you must have a simple, yet compelling, story to tell.

This is particularly true in the case of space. I am amazed at the lack of understanding that there is in Washington about what we do in space, why we do these things, and what direct benefits they provide.

To make the Space Exploration Initiative happen, government and industry are going to have to do a better job of explaining why we must return to the Moon and then go on to Mars.

(NEXT CHART)

I believe there are four basic reasons why Mars must be our destination:

One: There is evidence to suggest that life may have once existed on Mars, and only by being there can we find out for sure. Imagine the consequences to humanity of discovering that life as we know it, or as we do not know it, existed beyond the Earth. And if we find that life did not exist on Mars, that too is significant.

Two: Expeditions to Mars will focus our national energies and challenge our technology in ways which will benefit our country's economy, foster our competitive posture, improve our educational system, and enhance our sense of national pride. And these benefits will begin to accrue well before men and women ever arrive at the Red Planet.

Three: Mars offers the unique opportunity to unite the nations of the world in a long-term, peaceful endeavor where exploration replaces superpower conflict and where the emphasis in international relations becomes our common humanity. Farfetched? I don't think so. The world is changing, and the dynamics of the decades ahead are not likely to resemble the world that we grew up in.

Four: Mars responds to a fundamental need in all of us. There is a human imperative to explore. People must explore because they are human beings with a desire to expand the scope of human experience. Exploration adds to our knowledge, satisfies our curiosity, and responds to our sense of adventure. We are going to Mars because we are alive, and because it reflects something very special inside each and every one of us.

Given the fact then that we are going to Mars, why then are we first going back to the Moon? After all, we've already been to the Moon.

The answer is because it is prudent to do so. We are not ready yet to go to Mars. The Moon is close by and will enable us to develop the technologies, and operational experience we greatly need. And the Moon will provide us with great new science opportunities as well as providing other near-term milestones required to sustain public support for the much longer development of the Mars expeditions. Mars is a very

large technological challenge, and just as we conducted the Mercury and Gemini Programs as precursors to Apollo, so now will we make similar use of our opportunity to return to the Moon.

There is another story that NASA and industry need to tell as we travel about and talk to the many people who influence and make public policy decisions.

The subject is space technology, and, here again, I am amazed at the lack of general appreciation. Too many people seem not to recognize that our investments in space technology make possible the space programs we will have in the future, and that these same technologies lead directly to applications that affect the everyday life of most Americans.

Space technology is an investment. It means building for the future. It lacks some of the glamour of flight projects, but it is a vital part of our space program. To remain the preeminent spacefaring nation, the United States is going to have to expand its current technology efforts.

I am concerned about the level of funding for space technology. But, I am actually more concerned about the lack of appreciation of its importance. I think you should be concerned as well.

Together, we need to tell the space technology story and explain to people how absolutely essential these investments are. More specifically, we need to clearly portray to the typical American the near-term benefits of this technology to our everyday life here on earth.

Investments in new technologies are what's needed for the Space Exploration Initiative. That's one of the conclusions of NASA's 90-Day Report. This report summarized the technical analysis NASA has done over the years to understand what's involved in going back to the Moon and on to Mars. The report is a solid piece of work. Where it falls down is in its title. It was not 90 days of analysis, but rather a three-month effort to focus and put down on paper what we knew from a number of years of detailed work. Behind this report, for example, are six thick volumes of supporting technical studies.

These studies drew a number of specific conclusions.

We need a heavy lift launch vehicle. Current capabilities are not adequate for lifting the mass required for the Moon and Mars programs.

Robotic spacecraft will be needed. Just as Apollo relied upon Ranger and Surveyor, our expeditions to the Moon and Mars will need unmanned orbiters and unmanned rovers.

Scientific opportunities are considerable, both on the Moon and on Mars. Science is not the primary reason why we are doing this, but in so doing, we are going to conduct a very large amount of first-rate science.

Life sciences is an area where much work needs to be done. Our understanding of the effects on human beings of extended space flight is relatively limited. Before we embark on a three-year expedition to Mars, we will need to be confident that our astronauts will be able to function safely and productively.

One place to obtain the life sciences data we need is at the Space Station. Freedom is an integral part of the Space Exploration Initiative. President Bush specifically mentioned the Station in his speech last July, and the analysis in the 90-Day Report indicates that the Space Station is likely to be the staging area and point of departure for expeditions to both the Moon and on to Mars.

I believe we are building the right Space Station. It will support microgravity research, it will build the life sciences database we need, and it will evolve to meet the transportation requirements of SEI.

Lately, the Space Station Freedom Program has had its share of difficulties. For those on the sidelines, it is easy to criticize, particularly when the normal process of engineering problems and solutions is not well understood. In fact, as most of you well know, NASA and industry are making significant progress on the Station. Budget problems and the help we receive from outside may sometimes obscure this progress, but it is there nonetheless.

I believe Space Station Freedom is going to be a huge success. For the first time, we will no longer visit space, we will be there, living and working in low Earth orbit. The Station will provide in abundance three

precious space resources: volume, time in orbit, and crew.

With the Station up and running, the Moon and Mars come within our reach.

To get to the Moon and Mars, NASA and its partners--in industry, in the academic community, and in other Federal agencies--are going to have to couple their experience with innovation. We are going to have to combine how we did things in the past with new ways of doing business.

This is certainly the case within NASA even though how we did things before worked out pretty well more often than not.

So when the Vice President asked Admiral Truly to lead a national outreach program in search of ideas, concepts, and technologies which might benefit the Space Exploration Initiative, we responded positively. Working with the Space Council staff we have put together an outreach program designed to obtain ideas from across the country. We will be soliciting the views of technical societies and universities. We will be seeking advice and support from other agencies within the government and their laboratories. And Jerry Grey and the AIAA are helping us assess technologies by drawing upon the many talented individuals within the aerospace profession.

Let me say that I hope the companies where these individuals work will encourage their employees to submit ideas.

Right now we are assessing the outreach activity broadly within the government. The discussions are positive and, I am hopeful that we will be able to proceed with the outreach program requested by the Vice President in the very near future.

Of course, the outreach program will be just a small part of what is destined to become a very large, difficult, but very exciting program. In parallel with the outreach program, NASA will be continuing its own internal analysis which we hope to augment in the near future with complementary mission studies by the aerospace industry.

There is much work ahead of us, and a lot of decisions yet to be made. We have really only begun our preliminary planning. Some people think

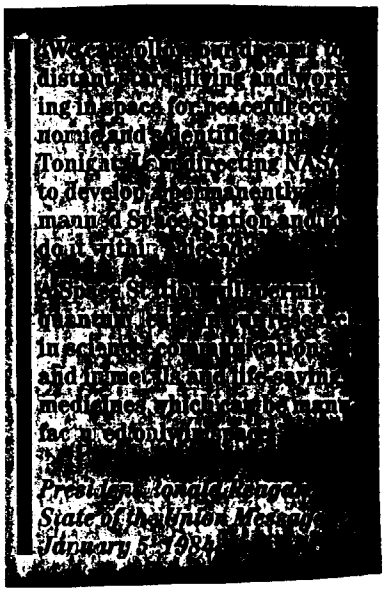
we need to wait awhile before starting but I do not believe this is the right path. We need now to invest in technology and to assess mission architectures such that in several years we will be in a position to put together a program plan which optimizes our opportunities for exploration its many associated benefits.

That's what we need to be doing, and that's why I am eager to get started.

At NASA we are ready to go, and looking forward to continuing our work.

I hope you are ready to join us.

Thank you very much.



"The success of the Space Shuttle and the advent of the Space Station focus our attention upon a basic question: Why do we have a civil space program? Why do we concern ourselves with rockets and satellites? My own view is that we have a space program not because of the excitement the program engenders and certainly not because the Russians have one. You have a space program because there are things you can do in space that you can't do on the ground. What things? Astronomy, materials research, navigation and communications, Earth observations, are all activities that lend themselves to space and there are others. Space has become simply a place where we do useful things."

Representative Bob Traxler, U.S. House of Representatives 8th District-Michigan

"A bird is an instrument working according to mathematical law, which . . . it is within the capacity of man to reproduce."

Leonardo da Vinci (1452-1519), Italian artist, engineer, mathematician, and scientist and one of the first known theoreticians on aeronautics.

"The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind . . .

"The aeronautical and space activities of the United States shall be conducted so as to contribute materially to . . . cooperation by the United States with other nations and groups of nations . . ."

From the U.S. National Aeronautics and Space Act which created NASA in 1958 and continues to guide its policies

"Exploration really is the essence of the human spirit, and to pause, to falter, to turn back on the quest for knowledge is to perish."

Astronaut Frank Borman, Commander of Apollo 8, the first flight by humans around the Moon, in address to the U.S. Congress, January 9, 1969, 13 days after returning to Earth.

"Our experience in space tells us that some tasks are best performed by automated equipment and that other tasks require the unique capabilities of man.

Tasks that are routine and which can be preprogrammed tend to be best performed by machines. Tasks that require initiative and judgment are more suitable for man. The Space Station will have plenty of both kinds."

John D. Hodge, Director, NASA Space Station Task Force

"With firm resolve and the commitment of reasonable resources over a number of years, Government and private enterprise working together can turn space into an arena of immense benefit for our nation."

L. J. Evans, Jr., Director, NASA Space Commercialization Task Force

"The infrastructure we will build will be no different than those we established to meet the great goals of earlier years. We established publicly-funded programs to support development of our highways, airports and railroads. The proposal to do the same for space will enable the commercial sector to work in partnership with government to open the realm of space to any number of promising enterprises."

James M. Beggs, NASA Administrator, at the White House briefing, January 26, 1984

Message to NASA From the European Space Agency

"Your nation's historic decision to build a permanent Space Station has created great interest on all sides. It is another manifestation of your nation's capacity to create, to adapt and renew, which has shown itself in many ways throughout your history. It will favour the development of new space techniques.

"Following President Reagan's invitation to the friends and allies of the United States to participate in the Space Station program, and based on our own scientific and technological capabilities, we are considering ways to join forces with you for the advancement of this project and at the same time challenge our own imaginations and skills. We hope that the Space Station will enhance the extensive transatlantic cooperation which has served our peoples on both continents so well in the past."

E. Quistgaard
Director General
European Space Agency

"To maximize the unique advantages provided by the environment of space, we need to establish a permanent presence that enables us to work in space full time . . . A Space Station is, I believe, the next logical step in space."

James M. Beggs, NASA Administrator, at a hearing before the Subcommittee on Space Science and Applications, U.S. House of Representatives, February 1, 1984.

"Silently drifting across the sky, it will resemble nothing so much as the imaginative creation of an inventive youngster with an Erector® set. It will consist of sleek metal cylinders, winglike panels, sinewy aluminum beams and long cranelike arms."

Description of the Space Station.* TIME, *February 6, 1984, p. 54.

"We can follow our dreams to distant stars, living and working in space for peaceful economic and scientific gain. Tonight, I am directing NASA to develop a permanently manned Space Station and to do it within a decade.

President Ronald Reagan State of the Union Message January 5, 1984

"The Shuttle is a central element of the Space Station endeavor. With both systems operational, the U.S. will have a capability to work in space unmatched by anyone."

Philip E. Culbertson, NASA Associate Administrator for Space Station, August 1, 1984

PUBLICATIONS AND PRESENTATIONS

This section includes material from NASA presentations and publications which is relevant to this year's topic. This section includes:

- "Office of Space Science and Applications: Strategic Plan 1990," all pages; Office of Space Science and Applications, NASA; 1990.
- Presentation on Space Exploration Initiative, selected pages; Office of Aeronautics Exploration and Technology, NASA; Spring 1990.
- "The Space Shuttle: The Journey Continues," selected pages; NASA; 1988.
- "Our Changing Planet: The FY 1991 U.S. Global Change Research Program," selected pages; Committee on Earth Sciences; January 1990.
- "EOS: A Mission to Planet Earth," selected pages; Office of Space Science and Applications, NASA; January 1990.
- "NASA Commercial Programs: A Progress Report 1989," selected pages; Office of Commercial Programs, NASA; 1989.
- "Aerospace Spinoffs: Twenty Five Years of Technology Transfer," selected pages; Office of Commercial Programs, NASA; 1988.
- "Space Program Benefits," selected pages; NASA; mid-1980's.

This report has been prepared as an internal OSSA document and it will serve as the basis for OSSA program planning in the future.

CONTENTS

Preface 2

Introduction 4
National Space Policy 4
OSSA Overview 6
OSSA Goals and Objectives 8
OSSA Principles 9
The OSSA Vision 10

The OSSA Strategy 14
The Core Strategy 16
Strategy for U.S. Global Change Research Program 17
Strategy for Space Exploration Initiative 19
Decision Rules for Integrating Overarching Initiatives 20
The Plan for 1991 21
Five-Year Strategy 27

Implications of the OSSA Strategy 36
Budget 36
Transportation 37
In-Orbit Infrastructure 38
Research Operations and Information Systems 40
Technology 42
Operational Medicine and Life Support 43
Institutions 44
International Cooperation 48

APPENDIX: The OSSA Scientific Disciplines—Individual Strategies 51
Astrophysics 52
Solar System Exploration 54
Space Physics 56
Earth Science and Applications 58
Life Sciences 60
Microgravity Science and Applications 62
Communications and Information Systems 64

FIGURES

OSSA Core Program Strategy, Including Initial Elements of Strategy for U.S. Global Change Research Program 34
Space Exploration Initiative Strategy 35

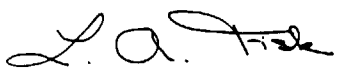
PREFACE

In 1988, the Office of Space Science and Applications (OSSA) developed and published a Strategic Plan for the United States' space science and applications program during the next 5 to 10 years. The Plan presented the proposed OSSA program for the next fiscal year and defined a flexible process that provides the basis for near-term decisions on the allocation of resources and the planning of future efforts. Based on the strategies that have been developed by the advisory committees both of the National Academy of Sciences and of NASA, the Plan balances major, moderate, and small mission initiatives, the utilization of Space Station Freedom, and the requirements for a vital research base. The Plan can be adjusted to accommodate varying budget levels, both those levels that provide opportunities for an expanded science and applications program, and those that constrain growth.

OSSA's strategic planning is constructed around five actions: (1) establish a set of programmatic themes; (2) establish a set of decision rules; (3) establish a set of priorities for missions and programs within each theme; (4) demonstrate that the strategy can yield a viable program; and (5) check the strategy for consistency with resource constraints. The outcome of this process is a clear, coherent strategy that meets both NASA's and OSSA's goals, that assures realism in long-range planning and advanced technology development, and that provides sufficient resiliency to respond and adapt to both known and unexpected internal and external realities.

The OSSA Strategic Plan is revised annually to reflect the approval of new programs, improved understanding of requirements and issues, and any major changes in the circumstances, both within NASA and external to NASA, in which OSSA initiatives are considered. This OSSA 1990 Strategic Plan refines the 1989 Plan and presents OSSA's initial plans for fulfilling its responsibilities in two major national initiatives. The Plan is now built on interrelated, complementary strategies for the core space science and applications program, for the U.S. Global Change Research Program, and for the Space Exploration Initiative. Each strategy has its own unique themes and mission priorities, but they share a common set of principles and a common goal – leadership through the achievement of excellence.

Calendar year 1989 heralded the beginning of a second golden age in space science. Like the first crisp notes in a symphony, the launches of Magellan, Galileo, and the Cosmic Background Explorer are to be followed in 1990 with a crescendo of activity to include the launches of Hubble Space Telescope, Gamma Ray Observatory, the Roentgen Satellite, the Combined Release and Radiation Effects Satellite, and Ulysses, and the flights of the Astro, Space Life Sciences, and International Microgravity Laboratory Spacelab missions. The challenge is to make certain that this level of activity is sustained through the end of this century and into the next. The 1990 Plan presents OSSA's strategy to meet that challenge.



L. A. Fisk
Associate Administrator for
Space Science and Applications

April 6, 1990

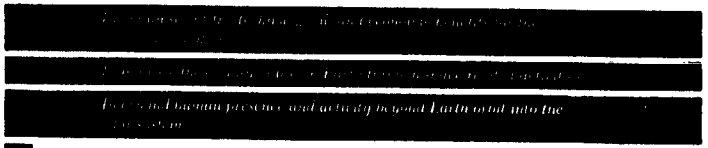
INTRODUCTION

National Space Policy

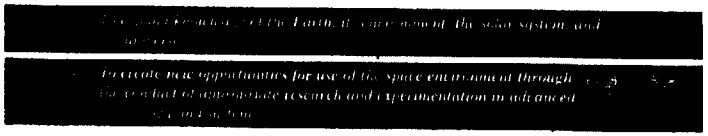
The National Aeronautics and Space Act of 1958 established NASA's mandate to conduct activities in space that contribute substantially to the expansion of human knowledge and "to the preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere."

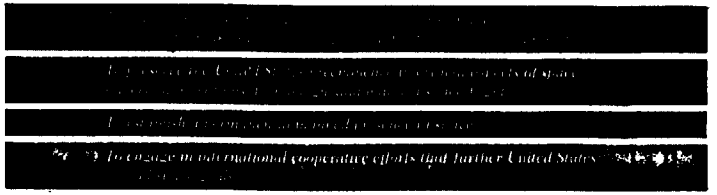
Three decades later, the Directive on National Space Policy, updated by the National Space Council and signed by President Bush on November 2, 1989, similarly states that "a fundamental objective guiding United States space activities has been, and continues to be, space leadership."

Leadership in space can only be maintained through the active, continuing development of a vital scientific research and applications program, and through the visible and significant achievement of the objectives of that program. Accordingly, the policy also states that some of the overall goals of the United States civilian space program are:



To achieve these goals, President Bush's 1989 space policy set forth the following objectives for civilian space activities:





Underscoring national space policy is President Bush's speech on July 20, 1989, commemorating the 20th anniversary of the Apollo 11 lunar landing. In that speech, the President shared his vision of NASA's future: Earth, the Moon, and Mars beckon as targets for understanding and future exploration. To safeguard the future of our own planet, he said: "A major national and international initiative is needed to seek new solutions for ozone depletion, and global warming, and acid rain. And this initiative – 'Mission to Planet Earth' – is a critical part of our space program." To move beyond Earth's boundaries into the solar system, the President proposed to the Nation "a long-range, continuing commitment. First, for the coming decade – for the 1990s – Space Station Freedom – our critical next step in all our space endeavors. And next – for the new century – back to the Moon. Back to the future. And this time, back to stay. And then – a journey into tomorrow – a journey to another planet – a manned mission to Mars."

National space policy reinforces traditional OSSA goals, and it affirms the fact that the United States embraces and supports both long-standing and evolving NASA goals. As its contribution to the President's U.S. Global Change Research Program, NASA has initiated the international Mission to Planet Earth, a concept that uses space- and ground-based measurement systems to provide the scientific basis for understanding global change. An initiative of particular urgency, Mission to Planet Earth builds on current OSSA Earth science missions to include three program elements – the Earth Observing System, Earth Probes, and Geostationary Platforms – to provide a constellation of satellites in a variety of orbits around Earth.

NASA has also been studying alternative approaches to human exploration of the solar system; most recently, a preliminary plan for a Space Exploration Initiative was developed in response to the President's speech. The role of space science and applications programs is critical: to ensure the safety, well-being, and evolving self-sufficiency of human space travelers, to conduct scientific robotic missions to characterize the environments of the Moon and Mars, and to plan for science investigations on and from the Moon and Mars.

Through programs such as these, NASA has always endeavored to expand the frontiers of discovery, understanding, human experience, and technology to enrich our Nation, ensure a position of leadership, and capture the benefits of space for humankind. As space science and applications programs open new vistas of knowledge, the possibilities for human exploration and habitation of space expand. Using the unique characteristics and perspective of Earth orbit, space science increases our understanding of Earth and the way in which we humans are changing its environment. The knowledge gained through observing our own planet from space stimulates new capabilities to improve life on Earth. And the critical technologies that are developed to enhance the exploration

and utilization of space can be transferred to the private sector to assure our economic competitiveness and contribute to the national defense. In all these ways, pushing the frontiers of knowledge and capability contributes to the realization of one of mankind's most compelling aspirations—to ever explore.

OSSA Overview

The Office of Space Science and Applications is one of the program offices of the National Aeronautics and Space Administration. OSSA is responsible for planning, directing, executing, and evaluating that part of the overall NASA program that has the goal of using the unique characteristics of the space environment to conduct a scientific study of the universe, to understand how Earth works as an integrated system, to solve practical problems on Earth, and to provide the scientific and technological research foundation for expanding human presence beyond Earth orbit into the solar system. OSSA guides its program toward leadership through its pursuit of excellence in space science and applications across the full spectrum of disciplines. The aspiration to excellence, combined with the active achievement of program goals, firmly positions U.S. space science and applications for an exciting, productive future.

The efforts of the OSSA program result in increased knowledge for all humanity. The scope of these efforts ranges from Earth's oceans and tectonic plates to the upper reaches of its atmosphere, and from our own solar system to the most distant galaxies. The pursuit of these objectives results in the development of tools, techniques, and procedures that can use the vantage point or characteristics of space to aid in the solution of major national and global problems and to contribute to the economic health and development of the United States.

OSSA pursues these goals through an integrated program of ground-based laboratory research and experimentation; suborbital flight of instruments on airplanes, balloons, and sounding rockets; flight of instruments and the conduct of life sciences and microgravity research on the Shuttle/Spacelab system and on Space Station Freedom; and development and flight of automated Earth-orbiting and interplanetary spacecraft. The program is conducted with the participation and support of all the NASA Centers, other Government agencies and facilities, universities throughout the United States, and the aerospace contractor community, with substantial international participation in many aspects of the program.

OSSA comprises nine Divisions. The Administration and Resources Management Division is responsible for OSSA fiscal and institutional management and for coordinating OSSA educational activities, public affairs, and Congressional relations. The Flight Systems Division is responsible for managing and integrating OSSA science and technology utilization of the Space Shuttle, Spacelab, and Space Station Freedom. The other seven are program Divisions, each of which emphasizes and applies a different scientific discipline to successfully accomplish OSSA's goals. These Divisions and their roles are:

Astrophysics, which has the goals of understanding the origin and fate of the universe and the birth and evolution of the large variety of objects in the universe, from the most benign to the most exotic; and of probing the fundamental laws of physics by examining the effects of extreme physical conditions on matter. The strategy for accomplishing these goals is based on contemporaneous observations across the entire electromagnetic spectrum.

Solar System Exploration, which has the goals of understanding the origin, evolution, and current state of the solar system and the planets, moons, asteroids, and comets within it, including the search for planetary systems around other stars; of understanding Earth through comparative planetary studies; and of establishing the scientific and technical data base required to support major human activities on other planets.

Space Physics, which has the goals of understanding the sources and interactions of particles and electromagnetic fields in the space environments of Earth and other solar system bodies; understanding the Sun as a star and as a source of interplanetary mass and energy; understanding the solar-terrestrial connection; and understanding the origin, transport, and interactions of energetic particles and plasmas, both within the solar system and throughout the galaxy.

Earth Science and Applications, which has the goal of understanding Earth as a system, including the interactive processes that maintain the global surface environmental balance, and those processes—both natural and anthropogenic—that are acting to change that balance. The strategy to accomplish this goal involves basic research to understand the physics, chemistry, and biology of interlinked Earth system processes, remote sensing from space for global-scale examination of Earth, and modeling and data analysis to provide a conceptual and predictive understanding of Earth as a system.

Life Sciences, which has the goals of ensuring the health, well-being, and performance of humans in space; developing an understanding of the role of gravity in living systems; expanding our understanding of the origin, evolution, and distribution of life in the universe; and promoting the application of life sciences research to improve the quality of life on Earth.

Microgravity Science and Applications, which has the goals of utilizing the unique characteristics of the spaceflight environment to conduct basic research in physics and chemistry, with special emphasis on fundamental phenomena, materials science, and biotechnology; of understanding the behavior of materials in a reduced gravity environment; and, where possible, of demonstrating the production of improved materials that have high technological utility.

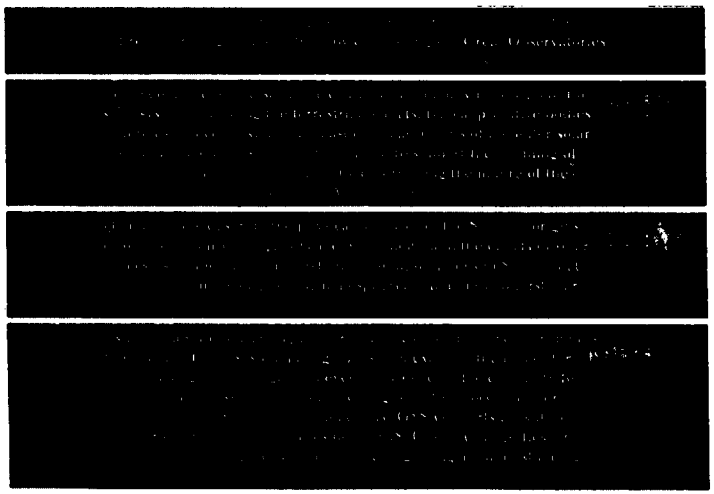
Communications and Information Systems, which has the goals of developing technologies to assure that the United States is in a position to make optimum use of the unique advantages of space-based communications systems; and of identifying and applying advanced communications and information systems technologies to meet the unique needs of the space science and applications program, the satellite communications industry, and the public sector.

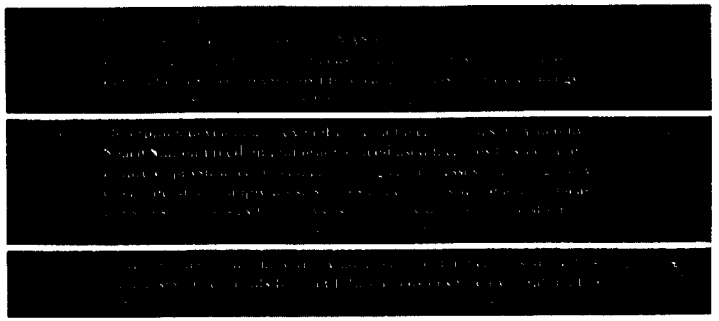
A more detailed discussion of OSSA's scientific disciplines and their individual strategies is provided in the Appendix.

OSSA Goals and Objectives

Advancing scientific knowledge of Earth, the solar system, and the universe beyond has traditionally been the focus of OSSA's activities. OSSA has always directed its energy toward using the unique vantage point and environment of space to study the universe, to understand the factors that influence our planet's environment, and to solve practical problems on Earth, and this pursuit remains a major component of OSSA's plans. OSSA is now undertaking Mission to Planet Earth, an integrated international satellite program for monitoring global change, coupled with a comprehensive data and information system. This program will generate long-term data sets for modelling global change processes, which policy-makers and scientists can use in formulating strategies for managing human impacts on global processes, such as greenhouse gases, ozone depletion, and deforestation. In addition, many current and future OSSA efforts will directly support the national goal of expanding human presence beyond Earth into the solar system by providing the scientific and technical research foundation that is essential for planning and implementing the President's Space Exploration Initiative. This foundation will be built by characterizing the environments and surfaces of the Moon and Mars, by determining the attributes of the space environment and establishing a scientific basis for understanding its long-term effects on human beings and their life-support requirements, by developing appropriate countermeasures to prevent or ameliorate any detrimental effects of human space travel, by conducting research in microgravity to support technology development, and by planning strategies for conducting science on and from the Moon and Mars.

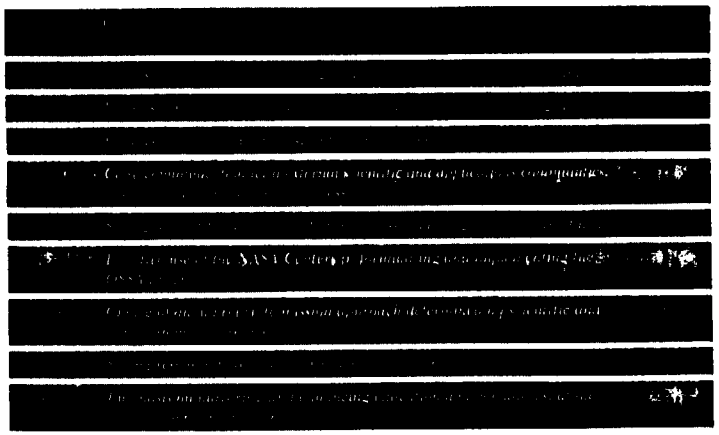
OSSA has established a number of near-term objectives that will guide its programs and plans for the future. These include (in no order of priority):





OSSA Principles

In the coming years, OSSA will continue to nurture the principles that have served it well in the past, including:



Especially important is the need for an increasingly interdisciplinary approach to major scientific problems. The importance of such an approach becomes progressively more compelling as the pursuit of solutions to major space research problems evolves to transcend some of the narrow and artificial boundaries between disciplines. Such problems cannot be solved without applying data and insights from many different fields. The future will see a continuing application of multidiscipli-

nary approaches in such areas as Earth system science; the origin of stars and solar systems; the origin, evolution, and distribution of life; the processes that cause all planets to form and change; and the information needed to conduct long-term human voyages beyond Earth.

The OSSA Vision

OSSA envisions that, at the dawn of the 21st Century, we will have successfully pushed back the frontiers of science and technology to further understand the past and to look into the future of our own planet, the solar system, and the universe.

Men and women will have travelled beyond the confines of their home planet, and will have begun to explore the Moon and Mars as they did the New World five centuries ago. Earth itself will be understood as mankind's home, limited in resources and requiring attention and care to preserve its delicate global balance. Instead of carelessly or ignorantly exploiting Earth, humanity will have a growing sense of responsibility for managing the use of the planet's resources in a renewable, sustainable fashion.

Led by the U.S., the international Mission to Planet Earth will have begun to build on the information gathered by earlier missions that studied Earth's global ozone changes, atmospheric dynamics, and ocean circulation. The nature and dynamics of the myriad components of the Earth system—core, mantle, crust, soils and land masses, global ecosystem, oceans, cloud cover, and the layers that compose the atmosphere—will have been observed and measured. Scientists will have begun to make progress toward describing how these intimately connected component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve on all time scales. The Earth Observing System and a complementary set of Earth Probes, major elements of the U.S. Global Change Research Program, will be obtaining long-term, continuous observations of our planet. Combined with ground-based measurements and observations, information received through these systems will be advancing our understanding of the Earth system on a global scale. These measurements will have been integrated into a comprehensive data and information system that scientists can access and use to understand and describe the global character of Earth. Earth system science will be on the way to developing the capability to predict those changes that will occur in the future, both naturally and in response to human activity.

Orbiting spacecraft will have traveled to every major solar system body that is accessible to us. One such orbiter will have visited Jupiter for a more detailed look, sending an instrumented probe through the gas giant's atmosphere and conducting an extraordinary 2-year tour of its Galilean satellites. The surface of Earth's sister planet Venus will have been mapped using radar that penetrates the dense Venusian clouds, substantially augmenting the information base necessary for the comparative study of Venus, Earth, Mars, and Earth's Moon. The history and future of our own planet will have become clearer through our increased understanding of our solar system neighbors.

We will have peered back into the early history of the solar system by studying its most primitive, unaltered bodies—comets and asteroids. One spacecraft will have flown for 3 years in formation with a comet in its journey around the Sun, deposited a sampling instrument into the comet's frozen crust, and embarked upon a 50,000-kilometer excursion down its spectacular tail. En route to its final destination, the same spacecraft will have studied an asteroid at close range, adding to a growing body of scientific information about these relics of our solar system's origin. Using a variety of experiments, other missions will also have studied asteroids of different compositional types, in order to understand their puzzling diversity.

Traveling farther into the outer solar system, a sophisticated spacecraft will be orbiting Saturn, closely observing its complex system of rings and moons and unveiling clues to the processes by which planets form. A probe will have descended through Titan's murky atmosphere, and a radar instrument will have revealed the nature of its invisible, possibly ocean-covered surface. In the atmosphere of this largest moon of Saturn, scientists believe that a chemical environment similar to that on early Earth exists. Studying this environment can teach us much, for it may be repeating some of the earliest steps in the processes that gave rise to life on our planet.

Our own Moon's global surface mineral and elemental composition will have been determined. Its global topography, gravity, and magnetic fields will have been measured, and an initial assessment of its resources, including a search for frozen volatiles at the poles, will have been undertaken. Combined with what we have already learned from ground-based studies and from previous missions, this information will help us to understand the Moon as a unique terrestrial body. This knowledge will also help prepare for the return of human beings to the Moon to build an outpost that will be both a site for scientific research and a way station for further human exploration.

Mars, with its Earth-like mountains, canyons, and evidence of ancient flooding, will have been studied extensively to determine the planet's climate, global surface processes, and behavior of its volatiles. These studies will characterize the environment in which spacecraft and crew must function to help us identify the most promising locations for further scientific exploration and plan for human expeditions to Mars, journeys that will expand human presence ever farther beyond Earth's orbit.

The Sun that gives us light and sustains life on our planet will have been studied both as a star and as the dominant source of energy, plasma, and energetic particles in the solar system. We will have begun to understand the Sun's interior and the origin of the solar wind, and to have the capability to predict the behavior of this star, which is central to the destiny of our solar system and of humanity. The results of Orbiting Solar Laboratory investigations will have increased our understanding of the Sun's variability and of solar particle eruptions. To extend that understanding and to provide early warning of solar events that might harm human explorers, orbital observatories will be in place at various locations to monitor all quadrants of the Sun's surface. A probe from Earth will be speeding toward the unexplored region between 3 and 60 radii from the Sun, where the solar wind first flows at supersonic speeds.

The nature of the interface between the interstellar medium and the interplanetary medium will have been determined, and the extent and three-dimensional structure of the heliosphere will have been mapped. Sources of galactic cosmic rays and the physics of their interactions with interstellar and solar system material will have been studied with the Advanced Composition Explorer orbiting the Sun, and with the Astromag facility on Space Station Freedom, which will have provided unprecedented information about nucleosynthesis, cosmic ray origin, acceleration regions, and

modes of propagation, in addition to searching for antimatter. We will be well on our way to comprehending how the complex plasma phenomena in different regions of the solar system and the Milky Way Galaxy are related.

Multiple spacecraft will have flown in close coordination to measure the total energy budget of the plasma processes in Earth's magnetosphere. The quantitative study of the geospace environment that is created by the interplay of solar and terrestrial processes will be progressing toward a full-scale predictive stage. Comparative observations of plasma processes at other planets will be well under way.

Four Great Observatories—the Hubble Space Telescope, the Gamma Ray Observatory, the Advanced X-ray Astrophysics Facility, and the Space Infrared Telescope Facility—will have fulfilled the goal of observing the universe across the entire electromagnetic spectrum. Complementary measurements will be obtained by the Stratospheric Observatory For Infrared Astronomy, which will be routinely flown in a Boeing 747 aircraft. As we begin to use the information these observatories reveal to us, our Nation will be recognized as leading a worldwide effort to understand our place in the universe. The revolution that this understanding will cause in our thinking will rival the one that occurred when an earlier astronomer, Copernicus, showed that Earth was not the center of the universe. Many totally unexpected scientific discoveries will be made; nature, unfettered by the limitations of human imagination, will continue to surprise and inspire us.

The question of whether the universe is expanding indefinitely, or will at some time begin to contract, should have been answered. The distance scales and the rate of expansion will be known with much better precision. Theorists, by combining data from the Great Observatories with experiment results from Earth-based particle accelerators, will develop models for the origin and fate of the universe that include unification of physical laws. Scientists, from workstations at their universities, will browse through astronomical data from the Observatories, and vast data sets will be quickly and conveniently accessible. Our understanding of the laws of physics will be revised to accommodate new insights gained from studies of relics of the creation of the universe and from observations of matter reacting to pressures and magnetic fields unimaginable in the vicinity of Earth, but common near compact objects such as neutron stars and black holes.

Our knowledge of the relationship of life to natural processes occurring in the cosmos will have been expanded, and a direct search for signs of life elsewhere will have been conducted. A sophisticated microwave observing project will have completed a comprehensive search for radio signals stemming from extraterrestrial technologies within a defined search space to extend our knowledge of life in the universe. We may, at last, know that life is not unique to planet Earth.

The effects of long-duration spaceflight on our most precious of resources, human life, will be known and understood. From Skylab, to the Space Shuttle, through extended-duration missions on Spacelab, to Space Station Freedom, and eventually on the Moon and Mars, we will have completed an evolutionary study of the reaction of biological systems, including human beings, animals, and plants, to low gravity and space radiation. We will have determined and developed measures to provide medical care in space and to ameliorate or prevent the physiological and psychological effects of long-term exposure to the space environment and the relative isolation that space travel, of necessity, imposes on our explorers. The provision of closed-loop life-support systems based on integrated bioregenerative, physical, and chemical processes will enable extended human exploration missions to the Moon and Mars.

Gravity's role in a wide variety of fundamental biological processes of plants and animals will be understood through our ability to explore the mechanisms of gravitational detection and response at all levels of life, from single cells to complex multicellular organisms. The systematic exploration of a wide range of gravity levels, available only through the use of suitable research facilities on extended-duration Spacelab missions and on Space Station Freedom, will be providing major applications on Earth.

Hand in hand with U.S. industry, academia, other Federal agencies, and our international partners, we will have begun to build on our experience with Spacelab to use the unique capabilities for microgravity research offered by Space Station Freedom. In the on-orbit environment, where conditions such as buoyancy, sedimentation, and convection are dramatically reduced, we will be using these characteristics to conduct critical experiments to test fundamental physical concepts. This pioneering research will be applied to advance science and applications in such areas as fluid physics, materials science, combustion science, health science, and biotechnology. Space Station Freedom, an operational international laboratory, will open a new frontier for microgravity science, a frontier that will challenge and motivate us, stimulate exciting developments in science and technology, and establish the scientific foundation for exploiting the commercial potential of space.

Advanced communications and information management technologies and computational facilities will be operating to support the transmission, acquisition, archiving, and analysis of the tremendous volume of data returning from all these instruments in space. The demand for communicating vast quantities of data will be met by commercially available communications satellite systems that have incorporated technologies derived from the Advanced Communications Technology Satellite. Globally separated research sites will be connected by high-data-rate channels operating over optical intersatellite links on Earth-orbiting satellites. New high technological risk components and subsystems provided by NASA will be significantly shortening the adoption time for advanced technologies and continuing the improvement of commercially available satellite communication systems.

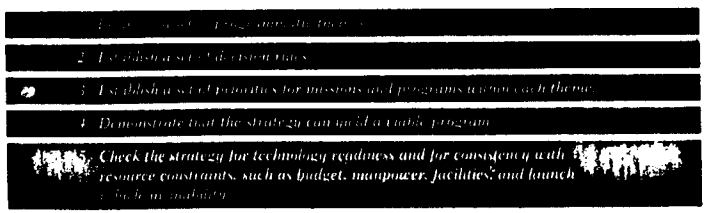
The success of our space program will be a source of great national pride, and it will attract our young people to develop the skills and knowledge that the Nation will need in the future. But perhaps the most fundamental reason for space science is that it expands the frontiers of discovery, understanding, human experience, and technology. The United States was founded by people determined to expand the frontier and to take advantage of that expansion to enrich our nation. This determination forms a part of our national character, and we can and must apply our efforts to realize our visions of exploring space and making its riches part of our lives. With a strong and supportive national will, we can proceed.

The basic premise of strategic planning is to develop a clear vision of a desired future; this is OSSA's vision. The strategy for realizing this vision is necessarily ambitious, yet it is firmly tempered to be realistic enough to succeed. Our vision sees NASA and the United States enjoying an exciting and productive era in space science and applications, with leadership in space manifested by visible achievements that are second to none.

THE OSSA STRATEGY

To shape an enduring program to make its vision a reality, OSSA has formulated a strategy that is the culmination of extensive interaction and collaboration with the scientific and applications communities, careful consideration of resource guidelines, and interactive reviews of pertinent issues and challenges.

OSSA's strategic approach is constructed around five actions:


4. Demonstrate that the strategy can yield a viable program
5. Check the strategy for technology readiness and for consistency with resource constraints, such as budget, manpower, facilities, and launch

Guided by OSSA's long-standing principles, these five actions define the process by which OSSA plans its activities and allocates its resources. The programmatic themes provide direction and balance, the decision rules guide us in choosing efforts among and within themes, and the priorities determine the order in which we pursue the missions and programs within each theme. By exercising these actions, various plans for an integrated OSSA program result, and these plans can be checked to determine whether they yield a viable program and are consistent with our resource constraints.

An important point to note is that exercising the above actions does not, nor is it intended to, result in a single plan. Rather, these actions define a realistic and flexible process that will provide the basis for making near-term decisions on the allocation of resources for the planning of future efforts. The least certain constraint on our planning is the budget level that will be available to OSSA. The process defined here allows us to adjust to varying budget levels, both those levels that provide opportunities for an expanding science and applications program and those that constrain growth.

In developing this strategy, we have assumed that the NASA budget will continue to grow to accommodate Agency plans, including Mission to Planet Earth and the Space Exploration Initiative, and that OSSA will receive the proportion of the overall budget that is consistent with its historical allocation and its expanded role in national initiatives. Further, we assume the implementation of current plans for a mixed fleet of launch vehicles, with the launch rates presently projected for the Space Shuttle and for expendable launch vehicles. (In general, expendable launch vehicles will be used for payloads that do not require crew intervention or other capabilities unique to the Space Shuttle.) The level of availability of the Agency work force is assumed to be consistent with current NASA projections, as augmented by needs associated with national initiatives.

As a result of the President's initiatives in Global Change Research and the human exploration of the Moon and Mars, the OSSA strategy is now composed of three interrelated, complementary parts. The first part is the core strategy that OSSA introduced in 1988. The second, an enhancement to the core strategy, reflects OSSA's lead role in the multinational Mission to Planet Earth, a key element of the U.S. Global Change Research Program. The third encompasses a strategy to fulfill OSSA's role in the Space Exploration Initiative.

The core strategy defines a program that OSSA should pursue even in the absence of overarching national and Agency initiatives. When such initiatives are undertaken, the appropriate resources must be added over and above the baseline. It is particularly important to note that the initiation of Mission to Planet Earth represents more than the beginning of a traditional OSSA science program. It also reflects NASA's role in a Presidential-level commitment to aggressively seek the understanding of global change needed to develop the predictive capability on which to base major policy decisions. Because the pace of Mission to Planet Earth is driven by this policy imperative, it will require a long-term commitment of resources to support that pace while preserving the vigor of the ongoing core space science and applications program.

OSSA's participation in the Space Exploration Initiative will be scaled to match the level and pace of the program for the Agency as a whole. The magnitude of each element of OSSA's contribution will be driven primarily by the pace at which the Nation proceeds and by the total institutional capability to pursue those activities in a way that adheres to the principles of excellence, balance, and appropriateness of approach.

Finally, in developing the strategy, no explicit assumptions are made about the level of international participation. Instead, we define our strategy and then move forward to seek opportunities for international cooperation to fit our plans. The strategy also preserves the flexibility to respond meaningfully to new international opportunities or initiatives. For example, in the event of a national decision to embark on a major new international collaborative program, the strategy will serve as the starting point from which we will shape the OSSA program to integrate new initiatives into the total science and applications effort.

THE CORE STRATEGY

Within the guidelines and assumptions discussed above, five basic themes drive the development of OSSA's core strategy.

Programmatic Themes

1. The Ongoing Program.
First and foremost, for missions in the ongoing program, the scheduling, resource allocations, and manifested slots on the Space Shuttle or an expendable launch vehicle must be protected and assured. The same high level of priority applies to ongoing research programs and mission operations and data analysis activities.

2. Leadership through Major and Moderate Missions.
OSSA plans to move boldly forward to make fundamental and visible advances in key areas of space science to ensure that our world leadership is preserved in the future. Our pursuit of leadership is most conspicuous through major and moderate missions, because they provide the largest quantum leaps in the advancement of scientific knowledge and technological ability.

3. Increased Opportunity with Small Missions.
Small missions are vital to the program because they can be accomplished relatively quickly and inexpensively, allowing continuing opportunity for consideration of innovative ideas for focused scientific objectives. The small missions are particularly important for training the next generation of scientists and engineers. since the missions are of a size that universities can develop, and the development and flight of small missions can occur in the same amount of time as that required to earn a graduate degree. These types of opportunities also build the experience and qualify the technology for major and moderate missions.

4. The Transition to Space Station Freedom.
Beginning with Spacelab and other in-space facilities, we are moving aggressively, but sensibly, to develop the principal areas of space science and applications that will take advantage of unique Freedom Station opportunities, such as pressurized laboratories for microgravity science and life sciences research and the multidisciplinary use of attached payloads.

5. The Research Base.
The research and analysis program provides base support for a vigorous and productive research community, and it presents a special opportunity for students to develop the skills that will enable them to conduct the programs of the future. The program consists of ground-based laboratory and suborbital research, data analysis, theory and modeling, and advanced technology development.

Decision Rules

The first step in the process of determining mission priorities and sequence is the establishment of a realistic budget level. Then, the five themes described earlier provide the template on which the OSSA core program is built. Ideally, at least one new initiative for each theme, except the ongoing program, would be included each year, and we would systematically pursue each item under each theme, in sequence by priority. However, in the event that the budget or other aspects of the external environment do not accommodate simultaneous enhancements in all four areas, certain rules have been formulated to determine the mix of program elements.

1. Complete the ongoing program.
Completing the ongoing program always has the highest priority; resources allocated to those programs already under way will not be sacrificed or postponed in order to pursue new starts.

2. Initiate a major or moderate mission each year.
Major missions preserve and enhance U.S. leadership in key areas of space science and applications, and we will pursue major missions whenever available resources allow us to do so. If an assessment of foreseeable expenditures for candidate missions, over both the near term and the lifetime of the program, indicates that our resources do not permit a major mission, we will pursue a moderate mission.

3. Initiate small missions in addition to major or moderate missions.
We endeavor to start a small mission or a small mission program every year, in conjunction with either a major or moderate mission.

4. Move aggressively, but sensibly, to build science instruments for Space Station Freedom.
S.S. Freedom initiatives are determined by the pace and balance of the scientific disciplines involved, relevance to and compatibility with Freedom Station, and technological maturity of the initiative. We will move forward systematically to provide a complete set of fully developed facilities and instrumentation for Space Station Freedom.

5. Research base augmentations will be sought whenever they are warranted.
They are determined by the impact of the other elements of the program on discipline stability, progress, and future needs. Provisions for improving the productivity of the ground-based and suborbital facilities are particularly critical.

STRATEGY FOR U.S. GLOBAL CHANGE RESEARCH PROGRAM

The OSSA core program strategy has been enhanced to accommodate NASA's participation in the U.S. Global Change Research Program. Concerns about global environmental change have reached the highest levels of many governments throughout the world. Irrefutable evidence exists to show that human activity has altered Earth's nature by changing its landscape and the composition of its global atmosphere. As never before, the public, the Government, the private sector, and the media are being exposed to scientific evidence that suggests changes, such as potential global warming, changing sea levels, declining upper atmosphere ozone levels, and massive deforestation, can affect their lives and their economic status. However, although the potential for these changes has been recognized, researchers have not yet reached consensus on the causes, the long-term extent, or the consequences of many of them.

To reduce the scientific uncertainties associated with global change, President Bush has proposed a multi-agency U.S. Global Change Research Program. The goal of this program is "To establish the scientific basis for national and international policymaking relating to natural and

human-induced changes in the global Earth system." Contributions will be made by the National Oceanic and Atmospheric Administration, the Department of Energy, the Department of the Interior, the Environmental Protection Agency, NASA, the National Science Foundation, and the United States Department of Agriculture.

OSSA plays a particularly important role in the U.S. Global Change Research Program. We are to apply our expertise in remote sensing to use the global perspective that is available from space to understand how Earth works as a system. To this end, an integrated, comprehensive program, including space- and ground-based measurements, research, and data and information systems, has been developed. This program, Mission to Planet Earth, is unlike any other NASA space science program. It is not intended to increase incrementally our knowledge of Earth. Rather, it is intended to increase with all due haste our knowledge of all aspects of the Earth system to a sufficient level of understanding to make sound policy decisions. This will require aggressive and sustained funding, and will dwarf any past space science activity.

The Mission to Planet Earth is composed of four interrelated elements, each of which builds on or complements the others. The first element consists of near-term missions already part of the core program. During the next several years, our knowledge of Earth should increase substantially, as NASA will participate in 19 Earth science missions to study various aspects of how the Earth works. The Upper Atmosphere Research Satellite will make definitive measurements of the chemistry and dynamics of the upper atmosphere, and thus of ozone depletion. TOPEX/POSEIDON will reveal more about the circulation of the world's oceans than all the ships in history. The NASA Scatterometer will study wind stress on the oceans. The ATLAS Spacelab missions will study the atmosphere, and the Shuttle Radar Laboratory will observe the topology of the land. Our international partners, the Japanese and the Europeans, will also launch seven missions, some of which will carry U.S. payloads, and many of which we will help track in return for access to their data. And the National Oceanic and Atmospheric Administration will continue to operate meteorological satellites.

The second element of Mission to Planet Earth, the Earth Observing System (EOS), is composed of a series of well-instrumented platforms in polar orbit designed to observe concurrently the behavior of the atmosphere, the oceans, the land, and life on Earth. The platforms are sized to accommodate instruments that need to observe the Earth simultaneously, through the same column of air. The first platform, which will launch in late 1997, is devoted to measurements of Earth's surface and the conditions of the lower atmosphere. The second platform, which will fly 2½ years later, is devoted to measurements of the chemistry of the upper atmosphere, the circulation of the oceans, and the behavior of the solid Earth. Our international partners, the European Space Agency (ESA) and Japan, are planning to build platforms that include accommodations for U.S. scientific instruments. Some duplicate EOS instruments will be attached to Space Station Freedom to take advantage of its location in low Earth orbit. Supplementing these core components will be the third element, a series of smaller Earth Probe satellites with specialized instrumentation and orbits for investigations that cannot be accomplished otherwise. The EOS Synthetic Aperture Radar, which will provide complementary land surface information not accessible with passive instruments on the EOS platforms, and the fourth element of Mission to Planet Earth, large geostationary platforms that will provide continuous monitoring on a global basis, will be initiated at a later time.

To make optimum use of the data from these upcoming missions, we intend to improve computational capabilities in Earth science, and to enhance the access of researchers to these data through networks and archiving facilities. The EOS program includes an EOS Data and Information System (EOSDIS), essential elements of which will be brought online in the early 1990s, in advance of the launch of the EOS platforms. EOSDIS will be used to derive maximum information from existing and upcoming missions, and, in turn, the data from these missions will be used to test and perfect EOSDIS in advance of the larger data flows from the EOS platforms.

Data alone, of course, do not yield understanding. That will require scientists interpreting the data, developing concepts for the processes that control Earth, and building predictive models of its future. EOS also will effectively double the research community that will dedicate itself to understanding global change, and the program will support graduate fellowships to ensure the future continuity of this research base.

The strategy for implementing Mission to Planet Earth is quite straightforward. The first element, the evolutionary precursors, consists of missions that have been approved or are already flying. The second and third elements, the Earth Observing System and Earth Probes, are proposed for FY 1991. Current preparatory studies for geostationary platforms are laying the foundation for the future initiation of the final element of Mission to Planet Earth.

STRATEGY FOR SPACE EXPLORATION INITIATIVE

OSSA has also developed a third strategy for fulfilling OSSA's role in the national initiative for human exploration of the Moon and Mars. As defined by the President, the Space Exploration Initiative follows a progressive timeline beginning with Space Station Freedom in the 1990s, a return to the Moon in the next century, and then a human mission to Mars. In broad terms, NASA plans to meet these objectives by performing life sciences research and technology development on Freedom, conducting scientific robotic missions to support site selection, and developing and supporting permanent human outposts on the Moon and Mars.

Although the specific pace and implementation plans are not yet defined, NASA's preliminary approach to the development of outposts on the Moon and Mars consists of four phases. The first, robotic exploration, obtains data to assist in the design and development of subsequent human exploration missions and systems, demonstrates technology and long communications time operation concepts, and dramatically advances scientific knowledge of the Moon and Mars. The second phase, outpost emplacement, emphasizes accommodating basic human habitation needs, establishing surface equipment and science instruments, and laying the foundation for future, more complex instrument networks and surface operations by testing prototypes of later systems. The third phase, consolidation, further expands these capabilities, and the fourth phase, operation, entails a steady-state mode with the maximum possible degree of self-sufficiency.

The OSSA strategy for the Space Exploration Initiative is built around Space Station Freedom and the four development phases to encompass three themes.

1. Meeting Human Needs.
We will commit humans to long-term space activities only when we have developed an adequate understanding of the physiological and psychological effects of and countermeasures to space travel and habitation of nonterrestrial bodies. Currently planned life sciences research in the areas of medical and life support systems conducted aboard extended-duration Spacelabs, polar-orbiting biosatellites, and Space Station Freedom will help to develop that understanding. Other missions will be flown to characterize and provide warning systems for in-space radiation hazards. Later, life sciences research preparatory for Mars missions will be conducted at the lunar outpost. Significant technology development of systems to protect and support human space travelers must also be conducted. Areas of concern include radiation protection, reduced gravity countermeasures, medical care, life support, and resolution of behavioral and human factors elements. Additional research is also required in areas of fluid flows, low-gravity combustion and fire safety, and the mechanics of granular materials in low gravity to support other technology needs in advance of long-term spaceflight and operations on the Moon and Mars.

2. Robotic Exploration.
In addition to their inherent scientific objectives, robotic exploration missions will develop global information on the Moon and Mars to prepare for human missions and aid in outpost site selection. Robotic exploration will proceed in synergy with human exploration, and robotic missions will be pursued with equal emphasis on the parallel objectives of continuing to conduct fundamental science and preparing for human exploration. The collection of critical data to support planning of human exploration missions constitutes an activity that extends beyond OSSA's traditional role of conducting basic research from the perspective of scientific value alone. Therefore, OSSA recognizes an added responsibility to develop and implement these missions to serve other parts of the NASA program, in concert with their extension of the pursuit of OSSA's basic scientific objectives.

3. In Situ Science.
Science conducted on and from the Moon and Mars can take the form of local human geologic and exobiological exploration, more distant rover traverses, return of samples to Earth, the installation of scientific instrument networks for long-term observations in several discipline areas, and scientific research in pressurized laboratories. OSSA's selection of science activities will be based on merit and intrinsic scientific value. Choices will be made between available alternatives on the basis of value, cost-effectiveness, or specific advantages. In addition, in planning for science on the Moon and Mars, choices between human and robotic approaches will be made on the basis of appropriateness of approach to the particular objective.

DECISION RULES FOR INTEGRATING OVERARCHING INITIATIVES

The first step in the process of determining mission priorities and sequence for integrating Mission to Planet Earth and the Space Exploration Initiative into the core program is the establishment of a realistic budget level. Then, OSSA will approach the incorporation of new missions into the program by assessing how these overarching national initiatives also contribute to the objectives of the OSSA core program and meet established OSSA principles. In many cases, components of Mission to Planet Earth and the Space Exploration Initiative are also part of the core program. In fact, two of three new elements of Mission to Planet Earth—the Earth Observing System and Earth Probes—stem from the OSSA FY 1991 core program. The EOS Synthetic Aperture Radar, which is deferred to a later start, and the geostationary platforms, which will be initiated when feasible, are the only two remaining elements of the U.S. Global Change Research Program strategy. The pace of incorporating these two elements will be driven by national policy, but constrained by the state of technological readiness to pursue them.

The strategy for the Space Exploration Initiative is somewhat less mature. The Lunar Observer, Lifesat, and the Biomedical Monitoring and Countermeasures program are missions of both the OSSA core strategy and the Space Exploration Initiative strategy. However, for the longer term, incorporating elements of the Space Exploration Initiative into the program will be an important strategic activity.

Ideally, at least one new initiative for each Space Exploration Initiative theme described earlier would be included each year, and we would systematically pursue each item under each theme in sequence by priority. However, in the event that the budget or other aspects of the external environment do not accommodate simultaneous enhancements in all three areas, certain rules have been formulated to determine the mix of program elements for the Space Exploration Initiative. These rules would also guide the timing of the initiation of the EOS Synthetic Aperture Radar and the geostationary platforms into the U.S. Global Change Research Program strategy.

1. **Match the pace of the OSSA program for overarching initiatives to the pace at which NASA and the Nation proceed as a whole.**

2. **Establish a feasible pace and scale.**
   The pace and scale of the total program will always be matched to the capability of the NASA institutional infrastructure and of the scientific and industrial communities to accomplish these missions.

3. **Preserve program balance.**
   OSSA will always adhere to the principle of scientific balance among the disciplines; the core program must proceed in parallel with overarching national initiatives. Mission sequence and priority will, therefore, depend to the extent possible on how various alternatives affect the balance of the overall OSSA program.

THE PLAN FOR 1991

The Core Program

The five programmatic themes and the rules for decision-making were followed in the construction of our fiscal year 1991 core program plan, as enhanced by the U.S. Global Change Research Program strategy.

ONGOING PROGRAM

The FY 1991 plan includes sufficient resources to operate and use the fleet of more than a dozen currently flying U.S. research spacecraft and to keep each ongoing flight project development program on schedule for launch in its manifested slot on the Space Shuttle or an expendable launch vehicle.

Major events in space science and applications for calendar years 1990 through 1996, summarized on the inside back cover, indicate a vital and productive ongoing program. The year 1989 began a new era in space science and applications, as the Magellan mission to Venus, the Galileo mission to Jupiter, and the Cosmic Background Explorer were launched successfully. The program's momentum will continue to increase in 1990 in a full range of scientific disciplines with the launches of Pegsat, the Hubble Space Telescope, the Roentgen Satellite, the Gamma Ray Observatory, the Combined Release and Radiation Effects Satellite, Ulysses, and three Spacelab flights: Astro/ BBXRT, the first Space Life Sciences mission, and the first International Microgravity Laboratory.

Development continues on the impressive array of major, moderate, and small missions to be launched from 1991 through 1997. Initiatives and programs approved in FY 1990 are now underway as part of the ongoing program. A major communications mission, the Advanced Communications Technology Satellite, is being developed on schedule for a 1992 launch. Two major solar system exploration missions are now beginning development: the Comet Rendezvous Asteroid Flyby will be launched in 1995, and Cassini will begin its journey to Saturn in 1996. The Advanced X-ray Astrophysics Facility is being developed for a 1997 launch. The Explorer program continues and has been expanded to include the preparation of three small missions to begin launching in 1992. The SETI Microwave Observing Project continues instrument development for the 1992 initiation of observations.

The ongoing program also includes preparations for research missions on the Space Shuttle to encompass additional Space Life Sciences flights; a series of International Microgravity Laboratory, U.S. Microgravity Laboratory, and U.S. Microgravity Payload missions; several Atmospheric Laboratories for Applications and Science; several flights of the Shuttle Solar Backscatter UltraViolet instrument; and three flights of the Space Radar Laboratory. The Extended Duration Orbiter Medical Program has been defined and is operationally collecting data and refining protocols to certify the capability of the flight crew to safely pilot the return of the Shuttle and leave the spacecraft following extended-duration flights of 16 days. Under the theme of Space Station Freedom Utilization, we are developing a major life sciences centrifuge and six facilities in preparation for microgravity research on Freedom. The definition of first-generation attached payloads continues.

In considering the implementation of the ongoing program for this and any other year, our strategy must retain the flexibility to address alternatives for recovering from catastrophic loss (i.e., the loss of the spacecraft during launch or very early in its lifetime). The recovery process would strongly depend on the nature of the mission that suffered the loss; approaches to reliability and redundancy would be tailored to suit specific programs.

Generally, consistent with the high priority that is placed on the ongoing program, we would assess the alternatives for recovering the lost mission before pursuing any new projects or adding any new missions to the program. Several factors contribute to this assessment. We must consider the relationship of the mission to the discipline involved and determine the impact of the loss on the discipline's health. The urgency and relevancy of the science to be conducted are assessed; if the mission is a precursor to a future mission, that is also an important factor. The current state of technology would be compared to the technology used in the original design; near-term projects already in development might more than compensate for the loss.

Redundancy may, in some cases, be an integral element of the program. For example, the Mariner Mark II program is based on the use of a new generation of cost-effective, modular spacecraft that can be easily modified to accomplish a variety of missions to outer solar system targets. This approach has already been initiated with the approval of two missions: the Comet Rendezvous Asteroid Flyby (CRAF) and the Cassini mission to Saturn. Each spacecraft is designed to carry and use the instruments for either mission; therefore, in the event of an early loss of the CRAF spacecraft, the mission could be flown on the spare reserved for Cassini. A similar approach can be used for Mars Observer and Lunar Observer. For missions in near-Earth orbit, on-orbit refurbishment or repair is a possibility.

The related international implications of the loss and recovery would also need to be determined. In any case, cost will be a critical consideration, particularly because the OSSA budget does not carry the financial reserves to provide the contingency to cope with catastrophic mission loss.

LEADERSHIP: MAJOR AND MODERATE MISSIONS

OSSA's leadership program for FY 1991 is the Earth Observing System, the centerpiece of Mission to Planet Earth and an essential component of the President's U.S. Global Change Research Program. This major Agency initiative builds on evolutionary precursor Earth science missions to respond to the ground swell of public and Government concern about potential change in our global environment. The U.S. Global Change Research Program requires a comprehensive Earth monitoring system. Mission to Planet Earth meets this requirement, with the goals of understanding Earth as a global system, providing comprehensive, long-term, and continuous global Earth observations, providing an information system for access to these data, and building accurate, quantitative models to predict global change—and the consequences of such change—on both regional and global scales.

The Earth Observing System (EOS) includes two series of polar sun-synchronous orbiting platforms, payloads attached to Space Station Freedom, and the EOS Data and Information System, which will provide for the reception, processing, archiving, and distribution of EOS data, with interfaces to interagency and international networks that link it to the entire Global Change community. The information resulting from the EOS global remote-sensing observations is an important element in advancing knowledge of the fundamental processes that determine Earth's global environmental balance, including:

The hydrological cycle, involving interactions of land, sea, atmosphere, vegetation, and topography

Biogeochemical cycles, concerning global distribution and variation of biomass and the fluxes of tropospheric gases and aerosols

Climatological role of variables such as wind, pressure, temperature, cloudiness, and precipitation

Geophysical processes, such as the interaction of physical and biological functions in the ocean and the land that modify Earth's surface.

EOS will establish an international Earth observing and data system capability to operate for at least 15 years. In addition to two series of U.S. platforms, the European Space Agency (ESA) plans to provide two series of platforms, and the Japanese are planning one series. At least one

ESA and one Japanese instrument will fly on the U.S. platforms, and U.S. instruments will fly on the ESA and Japanese platforms.

In 1989, NASA selected eight facility instrument complements and their associated team leaders and members, 23 research instruments and investigator teams to be provided by principal investigators from various U.S. universities and research institutions, duplicates of three EOS instruments to fly on Space Station Freedom, and 28 teams of researchers for interdisciplinary EOS studies. These investigations include studies of climate modeling, biosphere-atmosphere interactions, the terrestrial carbon budget, deforestation, desertification, the global water cycle, global biogeochemistry, and the global radiant energy budget.

The global remote-sensing observations planned from EOS are extensive and comprehensive. The first observatory series includes instruments to investigate the land surface biogeochemistry and ecology, ocean productivity, geology, polar ice, and lower atmospheric dynamics and climatic processes. The second series concentrates on upper atmospheric chemistry and physics to continue the investigations begun by the Upper Atmosphere Research Satellite. In addition, the second series will build on the investigation of the ocean surface, circulation, wind fields, and air-sea interaction begun by TOPEX/POSEIDON and the NASA Scatterometer on the Japanese Advanced Earth Observations Satellite, and it will examine plate tectonics and glacier dynamics.

A third platform, a dedicated spacecraft for the Synthetic Aperture Radar, is not part of the FY 1991 plan; it is deferred to a later start. The Synthetic Aperture Radar will contribute to several EOS mission requirements, including the physical and biological structure, state, composition, and dynamics of the land surface, including terrestrial and inland water ecosystems; the circulation, wind stress, and sea state of the oceans; and the extent, type, state, roughness, and dynamics of glaciers, ice sheets, snow, and sea ice in the global cryosphere. The Synthetic Aperture Radar provides penetration of vegetation cover and volumetric information not accessible with passive instruments in other regions of the electromagnetic spectrum, is independent of cloud cover, and provides data for both day and night.

The EOS platforms will be launched from the Western Test Range on Titan IV vehicles into polar sun-synchronous orbit, which provides for simultaneous global coverage every 3 days. The first platform series will begin with a launch as early as late 1997, and the second series will begin with a launch in 2000. Each platform, which will carry from 3,000 to 3,509 kilograms of scientific payload, will be designed for a lifetime of 5 years, and will be replaced twice to achieve a minimum mission life of 15 years.

SMALL MISSIONS

To maintain program continuity and vigor through frequent flight opportunities, three missions were added to the Explorer program during 1989. These missions are to be launched on small-class expendable launch vehicles to achieve first-class scientific objectives in physics and astronomy. Launches will begin in 1992, and we plan to approve more small missions in time to sustain a steady series of flights. In addition, the Total Ozone Mapping Spectrometer is being prepared for launch on a Soviet Meteor-3 satellite in 1991 and on a Scout-class launch vehicle in 1993.

A new small mission series in the FY 1991 plan is the Earth Probes, a line of Explorer-class spacecraft in Earth science that complement the Earth Observing System and provide for Earth science missions with highly focused scientific objectives that do not require a large set of simultaneous observations, or that do require specialized spacecraft or unique orbits.

Some science objectives of Mission to Planet Earth cannot be accomplished from EOS. These include observation and monitoring of processes, such as rainfall, which operate on diurnal time scales. Thus, the Tropical Rainfall Measurement Mission has been defined as one of the early missions in the Earth Probe series to examine the cycle of evaporation, evapotranspiration, and rainfall in the tropical regions; this cycle forms the heat engine of our global atmospheric circulation patterns.

The Earth Probes series, together with the Upper Atmosphere Research Satellite and TOPEX/POSEIDON missions now in development, provides for the additional capability to obtain vital global Earth observations in advance of EOS. Examples of such observations include the global ozone measurements currently being made by the Total Ozone Mapping Spectrometer on the Nimbus-7 satellite launched in 1978, and ocean productivity measurements interrupted in 1985 by the failure of the Coastal Zone Color Scanner on Nimbus-7. The global ozone measurements will be continued via the Earth Probes line with the launches of three Total Ozone Mapping Spectrometer instruments: on a Soviet Meteor-3 satellite in 1991, on a U.S. small-class vehicle in 1993, and on a Japanese Advanced Earth Observations Satellite (ADEOS) in 1995. The near-term Earth Probes will also support the flight of the Proteus Ocean Productivity Experiment. The NASA Scatterometer is also planned for flight in 1995 on ADEOS.

SPACE STATION FREEDOM UTILIZATION

The fourth theme of our 1991 plan concerns Space Station Freedom. In the coming year, the Space Biology Initiative, which provides flight hardware for conducting in-space research in space physiology, gravitational biology, controlled ecological life support systems, and exobiology using gas/grain simulation studies, will come into full development. The facilities provided by this initiative establish a core capability to support basic life sciences research requiring multiple specimen samples over extended periods of exposure to reduced gravity loading. The facilities also provide monitoring and analytical capabilities to support provocative challenges to a variety of living specimens over the complete lower range of the gravity variable.

In addition to the life sciences basic research program, a Biomedical Monitoring and Countermeasures program will be initiated to determine methods to maintain optimum crew health and performance and to medically certify repeated extended-duration tours of duty. The program is being designed to document specific factors limiting crew stay time on orbit, establish acceptable risk ranges of physiological adaptation that can be reasonably maintained on orbit, and design and validate countermeasures to maintain crew adaptation within levels acceptable to optimized mission operations. This program is an essential prerequisite to routine Freedom operations and is critical to the implementation of human exploration activities in space.

The 1988 EOS Announcement of Opportunity led to the selection of several flight projects and concept studies for attached payloads on the manned base, which are included in the EOS program to be initiated in 1991. Duplicates of selected polar platform instruments will be placed on Space Station Freedom to provide for additional coverage of low latitudes at all times of day and night. The duplicate instruments selected for the initial capability on Freedom Station are the Stratospheric Aerosol and Gas Experiment III for obtaining global profiles of aerosols and clouds, the Lightning Imaging Sensor for studying lightning and energetic atmospheric processes at low latitudes, and Clouds and the Earth's Radiant Energy System for measuring diurnal cycles in Earth's radiation budget at low latitudes.

Eleven attached payloads in astrophysics, space physics, solar system exploration, life sciences, and communications technology selected from the OSSA 1988 Attached Payload Announcement of Opportunity will be nearing completion of their definition phases, leading to decisions on actual development and manifesting for flight on the early Freedom Station. These flight projects, along with the concept studies also selected, will provide critical requirements both for the early Freedom Station configuration and for its evolution as a research platform.

Planning for the integration, transport, accommodation, and operations of these experiments will culminate in 1991 in an initiative for 1992 to develop necessary space and ground facilities to support internal and external Space Station Freedom utilization.

RESEARCH BASE

The fifth and final theme of our core program plan concerns the Supporting Research and Technology program, which is the vital foundation for a vigorous and productive research community. In the approved 1990 program, we are beginning augmentations to alleviate known funding problems to provide for a healthy research base, not only in 1990, but also over the long term. Key areas to be addressed are: maintenance of a stable suborbital flight rate, space physics research and analysis, ground-based instruments for solar system exploration, and mission operations and data analysis for astrophysics and Earth science and applications. Two new research base efforts will be initiated: the Life Sciences Specialized Centers of Research and Training and the multidisciplinary Origins of Solar Systems programs. The enhancements approved in each of these areas in FY 1990 will continue in FY 1991, but no new augmentations are proposed.

The Space Exploration Initiative Program

The three Space Exploration Initiative themes and the integrating decision rules were followed in the construction of our fiscal year 1991 plan for human exploration of the Moon and Mars, described below.

MEETING HUMAN NEEDS

Life sciences research planned as part of the OSSA core program will also play a key role in supporting the Space Exploration Initiative. The Space Biology Initiative, which provides flight hardware for conducting research on Space Station Freedom in space physiology, gravitational biology, controlled ecological life support systems, and exobiology, will come into full development. Planning for a Biomedical Monitoring and Countermeasures program will also be initiated to determine ways to maintain optimum crew health and performance and to medically certify repeated extended-duration tours of duty. These two activities combine to begin the strategy for conducting life sciences research on Space Station Freedom. In 1991, we will also complete definition studies to permit the first launch as early as 1994 of Lifesat, a recoverable biosatellite that will support critical experiments needed to quantify the effects of space radiation on biological systems.

ROBOTIC EXPLORATION

Development of the Mars Observer will be continued to prepare for a 1992 launch. The ground data and software systems will be enhanced to enable higher-resolution imagery to assist in the landing-site selection process for future robotic and human missions to Mars.

The Lunar Observer, OSSA's highest priority new robotic mission of the Space Exploration Initiative strategy and an element of the core program, will provide an essential global scientific data base for the Moon by carrying out a 1-year mapping mission in lunar polar orbit. In FY 1991, definition studies will identify modifications to the Mars Observer design to meet Lunar Observer requirements. In addition, long-lead-time parts procurement will be initiated to preserve the opportunity for a 1996 launch. The Lunar Observer will globally measure the chemical and mineral composition of the Moon's surface, determine the surface topography and landforms, and measure the Moon's magnetic and gravitational fields. These data will produce a new understanding of the Moon as an individual terrestrial body. The mission will provide key support to future human activities on the Moon by determining critical surface characteristics and by providing an assessment of potential resources, including possible frozen volatiles at the lunar poles. The Lunar Observer will use spare instrument and spacecraft components from the Mars Observer mission.

IN SITU SCIENCE

In FY 1991, the Exploration Science Working Group and discipline subcommittees of the Space Science and Applications Advisory Committee will complete initial analyses of recommended science strategies and will identify critical advanced technology development priorities to support science on and from the Moon and Mars.

With a clear eye toward the next 5 years, this plan for fiscal year 1991 allows us to make significant progress toward achieving our goals. The U.S. space science and applications program has historically produced an outstanding scientific return on America's investment, and we expect this return to continue and grow through the implementation of our 5-year strategy, described next.

FIVE-YEAR STRATEGY

Beginning with the overarching goals of NASA as articulated by National Space Policy, and working through OSSA's goals and objectives, the themes and principles cited earlier form the basis for our strategy for fiscal years 1992 through 1996. When we apply the decision rules with appropriate consideration of budgetary availability, institutional capability, and the pace of both the U.S. Global Change Research Program and the Space Exploration Initiative, the queue for the OSSA program is nearly defined. Major missions were begun in FY 1989 and 1990 and proposed for FY

1991; therefore, budgetary considerations dictate that the new start for FY 1992 will be a moderate mission: the Orbiting Solar Laboratory. The next highest priority core program new start will be the Space Infrared Telescope Facility. This strategy, then, steps through most of the currently defined major and moderate missions.

The Core Program

ONGOING PROGRAM

Through each succeeding year, the flight projects and research programs started the previous years combine with those already under way to form the ongoing program. In all cases, the highest priority of OSSA's strategy is to carry out the ongoing program.

LEADERSHIP: MAJOR AND MODERATE MISSIONS

All the major flight projects in the 1991 ongoing core program will be launched by 1997; a new major flight project requires 4 to 7 years to develop. Thus, to pursue leadership in key areas, the next step is to select the successors to the ongoing program. Our approach to adding new major and moderate initiatives to the queue is to incorporate several missions at the same time, rather than one every year. In future strategic plans, we will add the next group of major and moderate missions in a series of steps.

Each OSSA Division Advisory Subcommittee of the Space Science and Applications Advisory Committee will assess candidate missions and initiatives for each strategic plan theme. This assessment will be guided by the overall science strategy guidelines formulated by the National Academy of Sciences. The subcommittees will maintain close coordination with the relevant committees and boards of the National Academy of Sciences, particularly the Space Studies Board.

Candidate missions of the highest priority will be placed in the subcommittee's long-term mission queue reflecting that subcommittee's priority in implementation of the missions. In order to avoid excessive oversubscription, consideration will be restricted to missions judged to be within no more than about 10 years of technological readiness. Major and moderate missions in the long-term queue will be the focus of studies and advanced technology development funding by the discipline. Missions that slip in priority may be removed from the queue. On a triennial basis, the Space Science and Applications Advisory Committee will review each Division strategy and its long-term mission queue for scientific validity and consistency with the overall OSSA Strategic Plan. When OSSA augments its 5-year queue of major and moderate missions, the Space Science and Applications Advisory Committee will evaluate the missions proposed by the subcommittees and assist OSSA in preparing an integrated queue.

The Space Science and Applications Advisory Committee will hold the first triennial review of Division strategies and proposed queues in the summer of 1991, and make its recommendation by fall 1991 in time for inclusion in the 1992 OSSA Strategic Plan. In view of the changing character of space science and applications, with the launches of many missions and the addition of Mission to Planet Earth and the Space Exploration Initiative, the Committee may also reevaluate the decision rules during this time frame. The Space Science and Applications Advisory Committee will review the Division Subcommittee positions on small missions, Space Station Freedom utilization, and the research base on a continuing basis and make recommendations annually at the annual May-June Space Science and Applications Advisory Committee meeting. The Aerospace Medicine Advisory Committee will recommend a strategy to address the human needs theme of the Space Exploration Initiative, in addition to other life sciences research areas.

One major or moderate new mission should be started per year. Although we recognize the fact that circumstances may present occasions where more than one core program new start is possible, and others where no new start is possible, an average pace of one per year is necessary to meet the goals of leadership in key areas and to assure vigor and continuity. On the other hand, given a realistic estimate of resource constraints, more than one core program new start per year cannot ordinarily be expected, because available resources for small missions and for research and analysis must be preserved. Depending on the pace of national initiatives, two new starts in some years may be necessary in order to maintain program balance.

The major and moderate missions in the current core program strategy are described below.

ORBITING SOLAR LABORATORY

The Orbiting Solar Laboratory, the highest priority mission for initiation as early as 1992, is an ensemble of instruments in sun-synchronous orbit designed to probe the Sun's fine-scale magnetic structures and to investigate the transfer of mass and energy across the photosphere and into the corona. The mission's objective is to study the fundamental magnetohydrodynamic processes of the Sun's atmosphere in visible and ultraviolet light at the limits of the spatial and temporal resolutions at which they occur. The Orbiting Solar Laboratory will provide the means with which to study the origin and evolution of features leading to solar flares and solar variability, which have profound effects on Earth's upper atmosphere, and which may affect aspects of global change measured by EOS. These same fundamental processes are thought to occur in other stellar and astrophysical systems, and, therefore, this mission provides important quantitative measurements with which to better understand the results from the Great Observatories. The understanding gained from these observations will also make an important contribution to our ultimate ability to predict the occurrence of energetic solar particle events that will pose health hazards to astronauts en route to and from or at the Moon and Mars. The Orbiting Solar Laboratory, therefore, will serve as a critical first step in determining the observations to be made by a network of solar monitoring stations that can provide early warning of solar events.

THE SPACE INFRARED TELESCOPE FACILITY

Fourth and last in the series of Great Observatories, the Space Infrared Telescope Facility (SIRTF), an 85-centimeter, free-flying telescope in high-Earth orbit, will be ready for initiation in 1993. Cooled to the extremely low temperatures required to obtain high-sensitivity infrared data, SIRTF will probe the distant and ancient universe with a sensitivity that will exceed that of current ground-based and airborne facilities by factors of one to ten thousand. Among its prime observational targets will be protogalaxies near the edge of the observable universe, colliding galaxies, planetary systems beyond our solar system, brown dwarf stars, and bodies within our solar system.

SIRTF's timely development will allow essential coordinated observations with the Hubble Space Telescope and the Advanced X-ray Astrophysics Facility as they operate for their planned 15-year lifetimes. Because the Gamma Ray Observatory instruments have large fields of view, and the mission will mainly operate in "survey" modes, the correlative analysis of gamma-ray data with infrared data can be accomplished with the Gamma Ray Observatory data archives. Conversely, the Hubble Space Telescope and the Advanced X-ray Astrophysics Facility have very small fields of view, and these missions must be directed at unusual or interesting targets observed by SIRTF.

SIRTF will operate in a complementary and synergistic manner with the Stratospheric Observatory for Infrared Astronomy (SOFIA). SIRTF, with its profound sensitivity, will probe the deepest reaches of the universe, where the "red shift" places the primary emission of many objects in the infrared regime. SOFIA will provide extremely high-resolution spectroscopy of relatively bright and near-infrared sources.

30

GRAVITY PROBE-B

Gravity Probe-B is designed to be a cornerstone test of general relativity. Einstein's universally accepted theory of special relativity ties together the structure of time and space. His theory of general relativity, which is far less thoroughly tested, ties together space, time, and gravity. This theory is on a much less secure experimental footing than the special theory, and alternative hypotheses exist. Gravity Probe-B will measure both the distortion of the "fabric of space time, imposed by the Earth's presence, and the subtle dragging of this fabric, predicted to result from the Earth's rotation. The influence of these effects will be seen in subtle precessional changes affecting the behavior of a set of four ultra-precision gyroscopes operating in a drag-free, superconducting environment. The required technology for this demanding undertaking has been under development since 1985. The key elements will be tested using a functioning prototype to be flown on a Space Shuttle flight prior to the science mission.

THE SOLAR PROBE

The Solar Probe will be humanity's first direct exploratory venture to the near vicinity of the Sun. The mission will study the unexplored region inward from 60 solar radii to within 3 solar radii of the surface of the Sun. With the objectives of understanding the mechanisms of coronal heating and solar wind acceleration, the Solar Probe will make in-situ measurements of the electromagnetic fields, plasma, and energetic particle populations in the region close to the Sun. The Solar Probe offers a unique opportunity for leadership in exploration of the heliosphere, and it has been cited by the scientific research community as a high-priority objective.

SMALL MISSIONS

Missions in this category are essential to sustaining the vigor of our scientific community because of their frequent opportunity for launch, perhaps as often as every 2 years per discipline. The small missions provide opportunities comparable to the continuing series of classical Explorers, which emphasize focused scientific objectives in astrophysics, space physics, and upper atmospheric physics.

Currently identified small missions of the 5-year plan include:

LIFESAT

Lifesat, a key element of both the core strategy and the space exploration strategy, is a small, recoverable, reusable orbiting biosatellite that can be used as an inexpensive platform for conducting life sciences (and possibly other) experiments. Lifesat in polar orbit will support critical radiation biological experiments—studies that will not be addressed in any other area of the U.S. space program. The Lifesat spacecraft can be launched on a variety of expendable launch vehicles and can provide up to 60 days of microgravity environment. NASA has had discussions with a number of potential partners in Europe, Canada, and Japan, who have expressed an interest in collaborating in such a series of missions.

31

MICROGRAVITY FUNDAMENTAL SCIENCE

A number of fundamental physical and chemical laws can be investigated through access to the low-gravity environment of spaceflight. The strategy to be pursued is to give much-needed flight opportunities to these investigations. The experiments will focus on challenging a broad range of contemporary theories, including those in condensed matter physics and general relativity. In the mid-1990s, an augmentation is needed to develop flight instrumentation to accommodate these investigations and pursue the use of dedicated Explorer-class payloads to facilitate these investigations. Where applicable, the Space Shuttle, Space Station Freedom, available commercial platforms, and dedicated free-flyers will be used as vehicles on which to conduct research. The scientific merit and desirability of developing opportunities in this area are cited by the Space Science Board in *Space Science in the Twenty-First Century: Imperatives for the Decades 1995 to 2015 - Fundamental Physics and Chemistry.*

SPACE STATION FREEDOM UTILIZATION

For this segment of our 5-year plan, we wish to continue developing an initial suite of Space Station Freedom research facilities that will be capable of supporting basic research in the space sciences. Such research requires a "core facility" that can be optimally instituted using the unique resources of Space Station Freedom.

A key factor in OSSA's preparation for Space Station Freedom will be the continued use of Spacelab, Space Shuttle mid-deck lockers, and other appropriate carriers to develop, test, and verify new improved instrumentation for subsequent use on S. S. Freedom. OSSA-sponsored studies will further refine U.S. instrument requirements through evaluating coordinated, multinational hardware development programs.

Two special facilities are planned for external attachment to Space Station Freedom. The Cosmic Dust Collection Facility is proposed for research in exobiology and planetary science. The purpose of the Cosmic Dust Collection Facility is to determine the orbital elements of individual cosmic dust particles (including meteorite and cometary debris and possible interstellar particles), to trap each particle in the least degraded manner, and to provide for the return of the collected particles to Earth, together with the orbital information required for detailed analysis. Studies of pristine particles of known origin can provide unique clues about the formation of the solar system and the fate of the elements and compounds that led to planetary bodies and the origin of life.

Astromag (Particle Astrophysics Magnet Facility) is being studied as a joint NASA-Italian Space Agency facility for the early Space Station Freedom. The core of the facility is a magnetic spectrometer based on a set of superconducting coils that produce an intense magnetic field. The facility is designed to accommodate at least two experiments operating simultaneously, and the experiments can be changed or serviced as required. The three investigations selected for first-generation observations will provide unprecedented information about nucleosynthesis, cosmic ray origin, acceleration regions, and modes of propagation, in addition to conducting searches for antimatter at unprecedented levels of sensitivity.

The study and selection of candidate second-generation attached payloads will also continue over the 5-year period.

RESEARCH BASE

The highest priority in this area is to enhance the research and analysis base that is essential to OSSA's program. The augmentations to the base approved in FY 1990 constitute critical fixes during the next 5 years to revitalize science programs to vigorous levels of activity and to provide adequate mission operations and data analysis support. In the future, we will not seek generic augmentations to the base, but only those that support new elements of the OSSA program, addressing very specific areas of focused activity to be added to the research base, such as the facility described below.

STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

SOFIA is designed to fly a 2.5-meter telescope above 99% of the Earth's atmosphere in the fuselage of a Boeing 747 aircraft to provide high angular and spectral resolution for infrared astronomy. The SOFIA program is a collaboration with the Federal Republic of Germany, who will provide the telescope system. SOFIA is the ideal system for studies of the near universe with the clarity of view and spectral resolution essential for correlative analysis with data from orbiting observatories.

The SOFIA is planned to fly by the mid-1990s; this facility will allow astronomers to observe, with good angular resolution at infrared wavelengths inaccessible from the ground, the fascinating infrared sources discovered by the Infrared Astronomical Satellite launched in 1983. This continuity will ensure that the U.S. community (the pioneers and developers of the field of infrared astronomy) will maintain a major role until SIRTF flies and the complement for infrared astronomy is completed.

As a suborbital program, the SOFIA has several unique and important characteristics. SOFIA can provide frequent flight opportunities—more than 100 missions (or flights) per year. Instruments developed by the university research community can be changed for every flight. This capability allows the latest technology to be continuously incorporated and provides the essential test-bed for the development of sub-millimeter wavelength instruments to be flown in the space observatories of the next century. SOFIA will accommodate a large "guest observer" community, which also involves the training and development of space scientists for the next century.

Space Exploration Initiative Program

The themes and integrating decision rules cited earlier form the basis for OSSA's preliminary 5-year plan for the Space Exploration Initiative. Although the schedule for the Space Exploration Initiative has not been determined, OSSA will support each progressive phase with the appropriate activities in the three themes described below.

MEETING HUMAN NEEDS

Life sciences research to support human exploration will progress incrementally as the program proceeds. In the early stages, Space Station Freedom will serve as a controlled test-bed for studying extended-duration human habitation of space and for developing and validating systems and elements, such as habitation and laboratory modules and life support systems, to be used later on the Moon and Mars. In the area of radiation protection, the Orbiting Solar Laboratory, a mission in the OSSA core program, will serve as a critical first step in learning how to predict the occurrence of energetic solar particle events. The Advanced Composition Explorer will provide crucial data on the intensities of both the solar and galactic cosmic rays that are the primary source of the radiation. Lifesat, a reusable biosatellite, will support critical radiation biological experiments.

Upon the initiation of the emplacement phase of the lunar outpost, the focus for life sciences research will shift to systems developed on the Moon itself. Early systems will be used to establish prototypes for long-term habitation, and later habitats will provide additional space for increased biomedical and life sciences research. The facilities will be used to simulate the eventual long-term stays anticipated for Mars missions. Also during this time, a global system of solar monitors will begin to provide an early warning system for solar particle events.

ROBOTIC EXPLORATION

Preparation for human missions to Mars will require a series of robotic missions after Mars Observer to support and verify landing site selection. For example, a Mars Global Network mission involving an orbiter and multiple landers can provide high-resolution surface data and extended-duration seismological and meteorological measurements. Then a mission to return samples of Mars to Earth for scientific analysis and determination of the potential for back-contamination is appropriate. Next, a Mars Site Reconnaissance Orbiter would provide detailed imaging to characterize landing sites, assess landing site hazards, and provide a data base for subsequent rover traverses and piloted surface operations. Finally, several Mars Rover missions could certify sites with the greatest potential for piloted vehicle landing and outpost establishment.

IN SITU SCIENCE

As with all elements of the Space Exploration Initiative, in situ science will become progressively more sophisticated as the program proceeds. At both the Moon and Mars, science capabilities should begin with local human exploration complemented by unmanned rover traverses and be followed by the emplacement of initial science instruments. Later, more advanced scientific instrument facilities can be built to broaden the range of observations, and pressurized laboratories can be used to conduct research in a variety of areas. For example, the characteristics of the Moon make it a unique site for astronomical observatories, in particular for arrays of optical interferome-

ters. The establishment of ultraviolet, visible, and infrared telescopes on the Moon will substantially contribute to studies of the terrestrial planets and the atmospheres and surfaces of the outer planets and their satellites. In addition, science from the Moon offers unique opportunities to conduct high-priority cosmic-ray physics research.

On Mars, exploration will address questions of geoscience, climatology, exobiology, and life sciences. In early stages, the mobility of human explorers will be limited, but dependable and versatile long-range robotic rovers will have been deployed.

Strategy Summary

The strategy for OSSA's core program, including initial elements of the strategy for the U.S. Global Change Research Program, is illustrated in Figure 1. Figure 2 illustrates the preliminary strategy for OSSA's role in the Space Exploration Initiative. As stated in the previous pages and illustrated by the figures, many areas and missions are common or complementary among the strategies. The specific timing and phasing of OSSA's Space Exploration Initiative strategy will match the pace determined by national priorities and capabilities. In future strategic plans, a more explicit phasing between the schedules of the two strategies will be developed.

Year	Ongoing Program	Major & Moderate Missions	Small Missions	Space Station Freedom Utilization	Research Base Enhancements
1990	Research and Analysis	CRAF/Cassini	Total Ozone Mapping Spectrometer	Space Biology Initiative Definition Earth Observing System Payload Definition	Research and Analysis and Mission Operations and Data Analysis Corrections
1991	Mission Operations and Data Analysis	Earth Observing System†	Earth Probes††	Space Biology Initiative Biomedical Monitoring and Countermeasures*	
1992	Operational Medicine	Orbiting Solar Laboratory	Lifesat*	Cosmic Dust Collection Facility	Stratospheric Observatory For Infrared Astronomy
THROUGH	Flight Projects	Lunar Observer* Space Infrared Telescope Facility	Microgravity Fundamental Science	Astromag Second-Generation Attached Payloads	Focused Research and Analysis, Suborbital, Advanced Technology Development, Data Systems Enhancements
1998	Spacelabs and Other Carriers	Gravity Probe-B Solar Probe			

* Also see Space Exploration Initiative Strategy
† NASA contribution to the U.S. Global Change Research Program; will require the later addition of the Synthetic Aperture Radar
†† NASA contribution to the U.S. Global Change Research Program

Figure 1. OSSA Core Program Strategy, Including Initial Elements of Strategy for U.S. Global Change Research Program

Phase	Meeting Human Needs	Robotic Exploration	In Situ Science
Robotics and Space Station Freedom	Space Biology Initiative* Biomedical Monitoring and Countermeasures* Lifesat** Orbiting Solar Laboratory Advanced Technology Development Life Sciences Test-Beds for Lunar Outpost	Mars Observer (with ground system enhancements*) Lunar Observer*** Mars Global Network	Opportunities Definition Advanced Technology Development
Lunar Emplacement and Mars Robotics	Lunar Mission Systems Mars Life Sciences Test-Beds	Mars Sample Return with Local Rover Mars Site Reconnaissance Orbiter	Teleoperated Rover Initial Astronomical Facility Lunar Geology Pressurized Rover
Lunar Consolidation	Global Solar Monitors	Mars Rovers	Pressurized Laboratories
Lunar Operation and Mars Emplacement	Mars Mission Systems	Additional Mars Rovers	Advanced Lunar Astronomical Facilities Mars Geology and Exobiology Meteorological Stations Unpressurized Rover Mars Science Network

* 1991 initiatives
** 1991 definition activities to preserve launch opportunity as early as 1994
*** 1991 definition activities to preserve 1998 launch opportunity

Figure 2. Space Exploration Initiative Strategy

IMPLICATIONS OF THE OSSA STRATEGY

Although the OSSA strategy is carefully constructed to provide a balanced program in space science and applications, it also results in an annual sequence in which specific disciplines are highlighted in an orderly progression. In FY 1989, special emphasis was placed on astrophysics (new start for the Advanced X-ray Astrophysics Facility) and on microgravity science and applications (new start for facilities evolving to use on Space Station Freedom). In FY 1990, we highlighted solar system exploration (CRAF/Cassini new start and "Origins of Solar Systems") and life sciences (Space Biology Initiative and Biomedical Monitoring and Countermeasures planning, plus a research base augmentation for Specialized Centers of Research and Training). Similarly, FY 1991 is the "year of Earth," with proposed new starts for the Earth Observing System and Earth Probes. This approach systematically infuses strength into each of our scientific disciplines one by one, thus building strength and vitality across the entire OSSA program.

OSSA also interacts with and relies upon other NASA and other agency (domestic and international) programs by creating requirements and opportunities in a variety of areas. Within NASA, the appropriate allocation of Agency resources among the various program elements will, therefore, be essential to the success of the OSSA program.

This section of the OSSA strategic plan provides a summary assessment of the implications of the strategy on other segments of national and international space activities. This section will be updated each year, based on continuing activities to refine our understanding of the implications in each area.

Budget

Using the decision rules described earlier, OSSA has constructed a number of alternative plans that serve to demonstrate that the strategic process will permit most programs discussed in the previous section to be accomplished. However, in times of continued budgetary constraint, the pace at which these programs are developed will be affected strongly by the Nation's ability to control the deficit and by the way in which NASA's overall budget fares in the context of broad national priorities.

The strategic process does provide the decision mechanisms for determining the composition of the OSSA program, consistent with the realities of the budget. For example, if we assume that the growth in the total NASA budget continues over the next several years at its currently planned rate and that OSSA receives a portion of that budget consistent with its historical allocation and its role in major national initiatives, then carrying out the ongoing program and initiating major missions at a rate of nearly one per year will be possible. In some years, however, the initiation of moderate missions may be dictated, as is likely to be the case in FY 1992. In most years, a steady sequence of small missions, appropriate Space Station Freedom initiatives, and selective augmentations to the research base can also be accomplished.

In a more constrained budgetary environment that provides for little growth, the development phase of major missions would be delayed or stretched out over a longer period of time. In this case, moderate missions may be initiated at a rate of one per year.

In order to protect other elements of the OSSA program from budget overruns in major and moderate missions, we have instituted a policy whereby a "descope plan" is instituted for each mission. This plan describes a prioritized list of actions to be taken in the event of cost growth. In this way, costs will be contained within the mission budget, without impacting other elements of the ongoing program.

The complementary strategies developed for OSSA's core, global change, and space exploration programs permit the initiation of a mission in more than one area in the same year, provided sufficient budgetary and institutional resources are available. However, if there were pressure to accelerate the pace of either Mission to Planet Earth or the Space Exploration Initiative while constraining OSSA to only one new start in a particular year, then maintaining a balanced overall program could become impossible.

Critical to all new initiatives in the budget is reliable access to space through a robust fleet of launch vehicles. In the past, the cost of maintaining spacecraft and Spacelab instruments on the ground, awaiting launch opportunities, has severely hampered our ability to manage program costs and to progress with new initiatives.

Transportation

The OSSA strategy assumes the implementation of NASA plans for a mixed launch vehicle fleet, including the current Space Shuttle system (with the fourth orbiter becoming available for flight in 1992) and the full range of existing expendable launch vehicles. A maximum permitted downweight of 230,000 pounds enables Spacelab missions with a fifth energy kit to fly on either Orbiter Vehicle 102 (Columbia) or, beginning in 1992, Orbiter Vehicle 105 (Endeavour), for up to 10 days. An Extended Duration Orbiter kit now under development will extend the potential on-orbit stay time to up to 28 days. Space Shuttle launch rates for Spacelab module missions continue to be two to three per year and for pallet missions one to two per year. During the period between initial man-tended capability and the point at which an eight-person crew permanently

staffs Space Station Freedom, OSSA is considering converting some of these Spacelab flights to Science Utilization Flights tied to the availability and capability of the operational manned base. Following the establishment of a full permanent crew complement on Freedom Station, OSSA plans to continue to use on the order of one to two Shuttle flights per year to test new experiment hardware planned for Space Station Freedom, to conduct science and applications research that does not require the very long-duration opportunities provided by Freedom, or to service free-flyers.

Regarding expendable launch vehicles, implementing the OSSA strategy requires the availability of "small" (Scout- and Pegasus-class), "medium and intermediate" (Delta-, Atlas/Centaur-, Titan III-class), and "large" (Titan IV-class) vehicles. Launch rates for expendable vehicles will average approximately two small and one to two medium or intermediate expendable launch vehicles per year, with large expendable vehicles required in 1995 and 1996.

The rate at which the strategy can be achieved can be substantially enhanced with the Advanced Solid Rocket Motor, which would allow significant increases for payloads delivered to the Freedom Station manned base during the assembly phase. Without this new capability, delivery of user equipment to Space Station Freedom would be delayed, or additional Shuttle flights would be required. Even with additional Shuttle flights, significant time and effort would be necessary to install, test, and check out the piecemeal delivery of user equipment transported to Freedom—an effort that can be largely avoided with an Advanced Solid Rocket Motor capability.

A current deficiency in transportation capability for planetary missions is the absence of a high-performance transfer stage that is equivalent to the cryogenic Shuttle/Centaur upper stage cancelled in 1986. The use of the lower-performance Intermediate Upper Stage for Galileo necessitated multiple gravity-assist swingbys at Earth and Venus, requiring costly design changes and increasing the travel time to Jupiter. OSSA currently intends to use the Titan IV or equivalent launch vehicles to support solar system exploration. However, until either a heavy-lift launch vehicle (such as the Shuttle-C) equipped with a high-performance cryogenic upper stage, or some version of an orbital transfer vehicle (combined with a capability for space-based assembly) becomes available, planetary orbiters will not be able to achieve efficient direct transfers between Earth and the outer solar system.

In addition to those capabilities presently available or planned within the Office of Space Flight (OSF) in support of OSSA, our strategy includes substantial utilization of sounding rockets, balloons, and aircraft in carrying out the science and applications programs. OSSA, in conjunction with OSF, is engaged in a continuing assessment of civil space transportation needs as part of a larger national effort focused on space transportation architecture studies. Each year, the OSSA strategy will form a basis for inputs to these assessments.

In-Orbit Infrastructure

The Earth Observing System will be launched from the Western Test Range using NASA's Polar Orbiting Platform. Although the Polar Orbiting Platform was initially designed as part of the Space Station Freedom program, the use of the polar platforms for EOS has resulted in a plan to transition the full development and management responsibility of the platforms to OSSA. The EOS payload and its platforms are designed to be launched on a Titan IV expendable launch vehicle and to be replaced in-kind every 5 years.

The early and mid-1990s will be devoted to developing instruments and testing concepts on Spacelab in preparation for utilization of Space Station Freedom. Prior to completing and outfitting on-orbit Freedom Station laboratory facilities, human space operations will continue to rely on the Space Shuttle and its associated Spacelab systems. Spacelab module missions of up to 10 days can be flown three times in a 12-month period on Space Shuttle Columbia and, beginning in 1992, on Endeavour as well. The Extended Duration Orbiter kit could also extend Spacelab missions to as many as 28 days. In order to assure crew safety and performance on extended-duration flights, an Extended Duration Orbiter Medical Program has been established.

During the transition from Spacelab science operations to Space Station Freedom operations, early utilization of Freedom Station is being considered. OSSA expects to operate approximately three Spacelab flights per year. It may be appropriate to use some of these flight opportunities for utilization flights to Space Station Freedom. This approach would provide early scientific return during the extended Freedom assembly period now under consideration.

Regarding Space Station Freedom itself, previous assessments indicated that OSSA could fully utilize the baselined accommodations and resources anticipated for the fully operational Space Station Freedom prior to the 1989 Configuration Budget Review. Subsequent proposed changes to and deferrals of some capabilities and the corresponding assembly schedule modifications have raised many issues concerning the ability of the rephased Freedom Station to accommodate and operate OSSA payloads. Some shortfalls, such as upmass and power, only the Space Station Freedom Program can remedy. Others, however, such as development of laboratory support equipment and payload-unique attachment equipment, could be provided by users, although adequate funds would need to be incorporated in OSSA budgets beginning in FY 1992. In particular, the ability to support small attached and rapid-response payloads is critical to OSSA's goal of supporting small science missions and frequent flight opportunities. Future OSSA programs will require power and external attachment accommodations in addition to those currently projected for the baseline Freedom Station.

The inclusion of a Freedom-based Orbital Maneuvering Vehicle for retrieving co-orbiting spacecraft, along with some limited capability at the manned base for changing out orbital replacement units on free-flyers and for replenishing cooling cryogens and fuel on free-flyers or attached payloads, could significantly enhance planned utilization of Freedom Station. Until the Orbital Maneuvering Vehicle becomes an element of Space Station Freedom, OSSA will use the Orbital Maneuvering Vehicle in the Shuttle-based mode to support on-orbit servicing of large free-flyers.

OSSA has extended its planning for Freedom Station utilization to include two science communities external to NASA. A Space Station Science and Applications User Board and an associated working group have been created to coordinate Federally funded U.S. science planning and utilization of Freedom. Starting at the level of Discipline Working Groups, these U.S. agencies develop integrated research plans in life sciences, materials sciences, astrophysics, Earth science, space physics,

solar system exploration, and communications. In its leadership role, OSSA will make its on-orbit and ground infrastructure available to assist these agencies. In addition, OSSA has initiated cooperative studies with its science counterparts in Canada, Western Europe, and Japan. This cooperation has already shown significant promise of enhanced accommodation and resource utilization through international science collaboration. This continuing multilateral science activity is expected to lead to increasingly close cooperation at the science discipline level.

Research Operations and Information Systems

Because the primary purpose of OSSA data and information systems is to obtain and provide easy access to research data, trends in the character of space research drive the evolution of these systems. For research in an early exploratory phase, the instruments tend to be relatively simple, the investigations are focused, and the flight operations and data handling are fairly straightforward. That environment will continue for some classes of investigation, especially principal investigator-class experiments, which tend to use the suborbital, Small Explorer, Earth Probe, and Space Station Freedom attached payload platforms.

However, many of the missions highlighted in this Strategic Plan are far more complex. The broad scientific questions addressed by these missions are multidisciplinary, involve widely dispersed investigator teams, and require the combination and analysis of data from many different sources. They involve coordinated and often simultaneous observations in many wavelength bands with high spectral, spatial, and temporal resolution over long periods of time. Such investigations cannot be conducted without substantial advances in the approach to research flight operations and data handling. In addition, the sheer volume of data to be acquired, transmitted to the ground, processed, distributed to investigators, analyzed, and archived for future use will increase several thousand-fold by the late 1990s. This factor also calls for new approaches to maintain research effectiveness.

OSSA planning for research data and information systems embraces the complete life cycle, beginning with instrument development and ending with data dissemination, analysis, and archiving. A broader multi-mission and multi-discipline thrust is being added to the traditional mission-by-mission approach. This new emphasis will provide better connectivity between the distributed resources, extend the range of technological capabilities, and broaden the spectrum of shared facilities. New project definition and progress reviews will address data handling resources and the use of existing capabilities, and will help assure budgets adequate to meet their needs.

A multi-tiered strategy has been adopted to meet the OSSA operations and data analysis challenge in this changing environment.

1. **Provide robust basic systems to meet the specific objectives of the individual missions:** The discipline program offices will continue to carry the primary responsibility for ensuring that specific mission research objectives are met.

2. **Enhance the capability for scientific research that encompasses multiple missions within major disciplines:** The discipline divisions will continue to plan and implement discipline-specific data management approaches. Discipline data systems will emphasize wide availability of information about data holdings, easier access to those data by all researchers, and improved connectivity between researchers for the interchange of data, information, knowledge, and ideas. Scientists will be explicitly involved in defining, planning, and implementing the operations and data analysis systems in both an advisory and working group capacity.

3. **Provide for a meaningful level of OSSA-wide interoperability, planning, and resource sharing:** The coordination of broad provisions for interoperability, research data standards and guidelines, and the management of specified common capabilities will be conducted as an OSSA-wide function under the oversight of an OSSA director-level board. OSSA will ensure that data and information systems achieve the needed level of connectivity between major disciplines, and will provide for resource sharing where advantageous. Data and information systems will be designed for maximum direct interaction by investigators in mission science operations and analysis consistent with safety, security, and resource constraints. A high-level master directory will ensure open and uniform access to information about space research data, regardless of discipline or location. Communication services are being expanded to support the full range of mission operations and scientific data exchange. This OSSA infrastructure also oversees major institutional facilities that transcend individual missions and disciplines, including the long-term archives.

4. **Build upon operations and data analysis capabilities existing outside OSSA:** OSSA will make more effective use of the space- and ground-based operations and data handling expertise, capabilities, and resources managed by the Office of Space Operations and other NASA offices. Working relationships with universities, other agencies within the United States, and other nations will be expanded to achieve greater access to valuable data holdings and to otherwise enhance the national and global research programs in which OSSA is involved. International collaboration will be integrated into the overall information systems infrastructure as defined through the science discipline requirements.

5. **Foster system evolution:** OSSA will work with the Office of Aeronautics, Exploration and Technology and other groups to stimulate and help bring about new technological developments needed for the future. The operations and analysis systems will be designed to facilitate the introduction of new technologies as they become ready for use.

Two key themes emerge in the evolution of the OSSA strategy for research operations and information systems. The first is the trend toward discipline-oriented data management systems that further the process of integrating the traditional mission data systems into more complete research capabilities for each major research community. The Astrophysics and Planetary Data Systems are good examples of this trend. The second theme recognizes the need for a systematic approach to meeting the need for certain common capabilities, which involves coordinated planning across NASA offices and with the broader national and international research and technological communities.

Technology

In developing our strategy, we assume the availability of technology that is currently the state of the art or near that level. In addition to depending upon continued efforts by the Office of Aeronautics, Exploration and Technology (OAET) in a wide range of spacecraft and instrument subsystems, OSSA currently is conducting Advanced Technology Development programs for the next major OSSA initiatives—the Earth Observing System, the Orbiting Solar Laboratory, and the Space Infrared Telescope Facility. The Solar Probe mission will present significant new challenges, especially in the areas of thermal protection and communication systems; therefore, advanced technology studies in support of this candidate major mission will also be needed. Advanced development assures the timely availability of proven critical technologies well before they are needed for full-scale development. This approach to risk and cost reduction is an important element of the OSSA strategy.

Future OSSA programs will benefit substantially from technologies generally associated with cryogenically cooled infrared and submillimeter wave detectors, optical interferometers, sensors, space-qualified lasers, space data and information systems, vibration isolation, automation and robotics, and artificial intelligence. Applications include ultrahigh density data storage on Earth-orbital and solar system exploration missions, autonomous experiment systems operations, telescience, telerobotic servicing, and orbital assembly. In addition, a number of technology areas have heightened relevance and impact in connection with OSSA's role in the Space Exploration Initiative. These areas include bioregenerative life support systems, autonomous sample collection and analysis, spacecraft aerobraking and aerocapture, and lunar-based assembly of scientific instruments.

OSSA is currently involved with OAET in planning the scope and content of activities within the OAET program that are of direct interest to OSSA. OAET programs in advanced sensor systems, cryogenics, advanced propulsion, autonomous rendezvous and docking, large space structures, and advanced communications continue to establish the technological foundation for OSSA missions in Earth orbit and deep space and on the Moon and Mars. The two offices have established joint technology working groups in the areas of sensors (especially for astronomy and Earth remote sensing at infrared wavelengths) and spacecraft data systems. OSSA and OAET have also initiated regular coordination activities to pursue development of critical technologies that will be needed for future OSSA programs in such areas as long-term Earth remote sensing from geosynchronous orbit, robotic exploration of planetary surfaces, and precision pointing and stationkeeping from orbiting platforms. In each case, OSSA defines science requirements, whereas OAET develops generic technologies and advanced devices that OSSA can later integrate into operating systems to meet its specific needs.

Establishing permanent human outposts on the Moon and Mars for research, development, and exploration will require a comprehensive understanding of processes in extraterrestrial environments when different gravity levels are encountered. Processes must be understood in the areas of fluid mechanics, combustion science, the mechanics of granular media, and materials processing. In fluid mechanics, the studies of multiphase flow and phase change are essential to understanding heat transfer processes under varying gravity levels. An understanding of capillary phenomena is necessary for fluids management. The study of mechanics of granular materials is important to understanding the properties of unconsolidated soils in reduced gravity. An understanding of combustion science is necessary for fire prevention and control in the extraterrestrial environment. Finally, the study of materials processing in different gravity levels is necessary for the production of commodities to support human presence.

Operational Medicine and Life Support

A key OSSA objective is to accommodate immediate life sciences requirements by conducting and coordinating all operational medicine, medical support, and life support activities within NASA, and to provide for future requirements by determining human health, well-being, and performance needs, and conducting research, both on Earth and in space, to establish medical and technology requirements to meet those needs for human flight missions. The character of studies conducted to provide for future requirements is in many ways distinctly different from the larger ensemble of research roles for OSSA.

During the last 20 years, space life sciences research has evolved from simply providing operational medical support and enabling human survival in space to seeking an understanding of the causative mechanisms underlying space adaptation, predicting related health-threatening issues, and developing more effective procedures and countermeasures. As a result, the life sciences program now covers a truly interdisciplinary field, both advancing scientific and technical knowledge in biomedicine and optimizing life support for human spaceflight, exploration, and safe return to Earth.

Traditionally, life sciences research has included an Operational Medicine Program providing a unique preventive and clinical medicine organization charged with ensuring crew health, safety, and performance. This Operational Medicine Program encompasses crew medical selection and retention standards, clinical medicine programs for each manned flight mission, certification of crews for spaceflight duties, longitudinal studies of active and retired astronauts, and an operational environmental real-time health monitoring and intervention program. Support is provided to the Office of Space Flight for health care and crew equipment development and testing (including life support systems) and escape systems development. The Operational Medicine Program provides requirements to the Biomedical Program in life sciences for research and development of countermeasures to mitigate changes due to spaceflight, and maintains the health data base to identify long-term adaptation mechanisms. In turn, the Biomedical Research Program establishes the scientific foundation for improving crew selection, medical care, training, and monitoring, and for enhancing crew productivity and protection in space. Biomedical research supports the Operational Medicine Program by providing environmental requirements and countermeasures, and medical knowledge for practice of the clinical and preventive medicine.

Human exploration of the Moon and Mars presents crucial new challenges for life sciences research and technology development in the areas of medical and life support systems. Fundamental differences between space and Earth—the lack of gravity, inadequate atmospheres, deep cold, and radiation—challenge space life scientists and mission designers to provide solutions and strategies to protect the health of crew members and sustain their lives in space. To this end, OSSA, in collaboration with OAET, is formulating a comprehensive program to provide the range of medical and life support capabilities and technologies necessary for the dynamic space missions envisioned for the next few decades.

Institutions

The successful accomplishment of the OSSA strategy depends on support from the NASA Centers, other Federal laboratories, U.S. universities, and the private sector. Internal to the Agency, OSSA has specific institutional management responsibilities for the Goddard Space Flight Center and the Jet Propulsion Laboratory; however, every NASA center is a direct participant in OSSA's science and technology programs, and the continuation of this support is essential. External to the Agency, the ongoing contributions of scientists and engineers at U.S. universities, at other Federal laboratories, and in industry are critical to the success of all OSSA programs.

NASA CENTERS

The NASA Centers are a national resource. The Centers themselves provide unique scientific research facilities, and the NASA civil service work force includes some of the Nation's and the world's finest scientists and engineers. Unfortunately, the facilities are aging, and the civil service work force has decreased substantially since the Apollo era. In order for OSSA to conduct a world-class program and meet the goals of this Strategic Plan, the Nation's investment in the NASA institution must be protected.

In the area of facilities, the NASA Centers need substantial maintenance, repair, renovation, and modernization. There is also a requirement for so-called "New Capability"; that is, new facilities that will enable the development, test, and operation of the more sophisticated and sensitive instruments envisioned in this plan. Examples of this type of capability are the enhancement of the LeRC low-gravity drop tube and the X-ray Calibration Facility now under construction at the Marshall Space Flight Center, which will provide the sophisticated capability essential for testing the Advanced X-ray Astrophysics Facility mirrors. In 1991, development will begin on the EOS Data and Information System facility at the Goddard Space Flight Center. This facility will house the critical data processing, archiving, and distribution functions for the EOS program, and it will accommodate members of the science community working with EOS data. Also included in the FY 1991 budget is funding for the Jet Propulsion Laboratory's Observational Instruments Laboratory, which will provide unique capability for developing large instruments for EOS and CRAF/Cassini.

NASA's civil service work force has decreased by more than 33 percent since the Apollo era. This decrease impedes our ability to manage major programs and limits our support to the science community. Particularly critical is the availability of qualified technical managers; NASA has successfully negotiated with the Office of Management and Budget for increases to this portion of the NASA work force. In addition, NASA will supplement its administrative staff, especially procurement personnel, so that the contract and grant interface with the scientific community and industry will be handled more effectively. The FY 1991 budget also contains a significant increase in the personnel needed for the EOS program.

In concert with the Centers and Agency management, OSSA will assess the current state and future needs of the NASA institutional base. A key first step was the "Center Science Assessment Team" activity conducted in 1987. This study identified strengths and weaknesses in the in-house space science and science-related technology program. NASA has begun to address the recommendations of the study report.

The following descriptions of the roles of the NASA Centers in the OSSA program are intended to identify the nature of the predominant activities of each center. The descriptions are not intended to be exhaustive and are not meant to imply any limitations on participation.

Goddard Space Flight Center – GSFC is involved in virtually all scientific disciplines within OSSA, with the exception of microgravity and life sciences. Personnel at Goddard have extensive experience in the management of science and applications satellite projects and instruments, including the Explorer program. GSFC is responsible for many critical support functions in the research base, including the operation of the NASA Space and Earth Sciences Computing Center, the Wallops Test Range, the National Space Science Data Center, and the sounding rocket and balloon program at the Wallops Flight Facility. GSFC has management responsibility for EOS, including the polar platforms and most initial Earth Probes. Goddard is the Flight Telerobotic Servicer development center and supports OSSA integrated Freedom utilization efforts in the areas of platforms and small attached payloads.

Goddard is also responsible for the scientific management and operation of the Hubble Space Telescope, as well as the Space Telescope Science Institute, where Hubble Space Telescope scientific data and operations planning will take place. Goddard also is responsible for managing the development and operation of the Gamma Ray Observatory, and in all likelihood will serve the same function for the Orbiting Solar Laboratory. Mission operations for a number of science and applications satellites are also conducted by Goddard. Under the management of the Office of Space Operations, GSFC runs the Tracking and Data Relay Satellite system and the near-Earth tracking and data acquisition network, which are essential to the operation of all U.S. Earth-orbiting spacecraft, balloons, and sounding rocket activities.

Jet Propulsion Laboratory – JPL is most often associated with the OSSA solar system exploration program, and indeed, the laboratory is a unique national resource in the development and scientific operation of deep space flight missions, including Galileo, Magellan, Mars Observer, CRAF/Cassini, and Lunar Observer. JPL will also play a critical role in the development of the future robotic missions of the Space Exploration Initiative. However, JPL plays a key role in most other areas of observational science and in the development of unique computational capabilities. The laboratory's development of synthetic aperture radar systems, as well as other instruments, is central to the OSSA Earth science strategy. JPL will also be responsible for developing the Space Infrared Telescope Facility and plays a limited, but important, role in the microgravity science program, specifically in the area of containerless processing. In addition, JPL supports OSSA efforts in studying evolutionary payload and on-orbit data handling requirements for Space Station Freedom.

Under the management of the Office of Space Operations, JPL operates the Deep Space Network, the worldwide tracking stations for planetary spacecraft.

Marshall Space Flight Center – MSFC has vast experience as a major system development center and, accordingly, develops and integrates major flight facilities for OSSA. Current examples include management of the development of the Advanced X-ray Astrophysics Facility, as well as mission management for the U.S. Microgravity Laboratory and most other Spacelab and Shuttle-attached payload missions. Continuation of Marshall's mission management role is critical to OSSA's effective

utilization of the manned base of the Space Station Freedom complex. MSFC provides overall management and integration of OSSA's science utilization management activities for Space Station Freedom. Less widely known, but very important, is MSFC's participation in the OSSA science and applications programs, particularly in space physics, astrophysics, Earth science, and microgravity science.

Ames Research Center—ARC is a major participant in the OSSA life sciences program in space physiology, artificial gravity, space biology, and exobiology. Ames has an active role in infrared astronomy, planetary sciences, and Earth sciences, in terms of both scientific research and the operation of the airborne science program (including the Kuiper Airborne Observatory, the ER-2s, the DC-8, and the C-130) and will build upon the successful operation of the Kuiper Airborne Observatory with the development and operation of SOFIA. In addition, ARC supports OSSA efforts in information systems and telescience for Space Station Freedom. Ames is the focal point in the Agency for exobiology research and for the SETI Microwave Observing Project.

Johnson Space Center—JSC plays a critical role in the OSSA life sciences activity, particularly in operational and space medicine and research on the effects of spaceflight on humans. JSC also participates in the solar system exploration program and manages the Planetary Materials Facility that preserves and distributes lunar samples, Antarctic meteorites, and cosmic dust. In microgravity science and applications, JSC has an ongoing program in biotechnology, as well as in the operation of the KC-135 aircraft, which is used for both life sciences and microgravity experimentation. JSC is also the mission management center for life sciences Spacelab missions and some Earth science and applications activity, including the flight of imaging radar on the Shuttle. In addition, JSC supports OSSA efforts in analytical integration of life sciences pressurized volume payloads, small and rapid-response payloads, and selected attached payloads for Space Station Freedom.

Kennedy Space Center—Because of KSC's operational character, the center's participation in the research program is limited to life sciences, particularly to playing a key role in developing controlled ecological life support systems. In keeping with its operational expertise, KSC is a major support center for Spacelab payload integration and maintenance of reusable Spacelab flight hardware; a similar role for KSC is expected to evolve in the Space Station Freedom era. The Kennedy Space Center processes the majority of spacecraft prior to launch on both the Shuttle and unmanned launch vehicles and is responsible for coordinating NASA launch activities at the Vandenberg Air Force Base in California. KSC also supports OSSA efforts in developing a management plan for science payload physical integration for Space Station Freedom.

Langley Research Center—Langley plays a substantial role in the Earth science and applications research program, particularly in the development of satellite experiments in the modelling of atmospheric chemistry, and in the analysis of climatic and other observations. LaRC also supports the materials science program for Spacelab and Space Station Freedom facility systems engineering, and provides fundamental research expertise in space radiation physics.

Lewis Research Center—LeRC is a key participant in the microgravity materials science and applications program, particularly in the disciplines of fluids, combustion, and metals and alloys. Lewis not only participates in the ground-based program by conducting research and operating a Lear Jet and drop facilities for microgravity simulation, but also contributes to the flight program by developing flight facilities and apparatus. LeRC has the lead role in the OSSA communications program and is responsible for the development of the Advanced Communications Technology Satellite.

Stennis Space Center—The Stennis Space Center is an important participant in the life sciences and the Earth science and applications programs, including operation of the Earth Resources Laboratory, which is involved in research in land/sea interactions and forest ecosystems.

U.S. ACADEMIC INSTITUTIONS

OSSA has traditionally considered the U.S. universities part of its institutional base and will continue to do so. NASA depends heavily on academia, not only as scientific investigators, but also as educators of the next generation of space scientists and technologists. The participation of U.S. universities is essential to maintaining a broad base of capability in areas vital to the future of space science and applications. In its 1986 report, entitled "The Crisis in Space and Earth Science," the NASA Space and Earth Science Advisory Committee cited a number of issues that are acutely important to the health of universities as key elements of the OSSA program. Among these issues were the need for a spectrum of small and large research opportunities, reliable and frequent access to space, attention to training and development of graduate students, and the stabilizing role of research and analysis. The OSSA strategy explicitly addresses those issues. OSSA intends to continue to work with its advisory bodies to assess the needs of the university community and to devise approaches to ensure that the unique long-term contributions that the community makes to space science and applications continue in the future.

Realizing the OSSA vision will require a trained and experienced academic community to analyze the vast amounts of data that will result from the accomplishment of the Plan. This need will be especially critical in the 1990s, when the launch of many missions will result in an unprecedented increase in data on significant science problems, at a time when many current members of the research community will be approaching retirement age. The science community may find itself inadequately prepared, both in technical capability and number of personnel, to deal with this onslaught of data. When combined with the projected decrease in science, mathematics, and engineering students over the next decade, these factors strongly stress the need for enhancing recruitment and training at the pre-college and undergraduate levels and for maintaining and increasing support for graduate students and postdoctoral researchers.

To respond to the growing concern over both NASA's and the Nation's needs for scientific and technical manpower at the turn of the century, OSSA is involved in a variety of programs that focus on education ranging from pre-high school to post-graduate levels. Examples include special educational programs tied to specific flight missions (e.g., the Astro and Space Life Sciences Spacelab flights), specialized residential summer courses (e.g., in life sciences, Earth science, and planetary science), graduate student fellowships (e.g., the Graduate Student Research Program and a new program in global change research), and special outreach programs to bring new colleges and universities into the space science and applications research arena (e.g., via the Joint Venture in Education or "JOVE" program administered through MSFC and the Historically Black College and University Program).

International Cooperation

Nearly all OSSA's ongoing and planned space science and applications missions involve some form of international participation. One of the principal means by which such participation is made possible is through OSSA's "Announcement of Opportunity" (AO) process, in which the international scientific community is routinely invited to submit proposals to NASA to fly foreign experiments on U.S. spacecraft, participate in U.S.-led experiment teams, and take part in post-flight data analysis activities. Foreign proposals compete on an equal basis with U.S. scientific proposals and undergo the standard peer review process prior to the final selection of participants. In keeping with long-established NASA policy, international cooperation in OSSA programs takes place on a "no-exchange of funds" basis, wherein each side agrees in advance to cover the costs associated with its own contribution to the activity.

In developing this OSSA strategy for leadership in space science and applications, no explicit assumptions were made about the level of international participation to achieve OSSA goals and objectives. Indeed, international space cooperation is not an end in itself, but a means of enhancing programmatic priorities. We intend to exercise international leadership first and foremost through a strong commitment to national vitality in our own ongoing program, major and moderate missions, small missions, use of Spacelab and Space Station Freedom, and maintenance of a vigorous research base. Only through an ambitious and broadly based national program in space science and applications will we continue to attract the best scientific and technical personnel from foreign nations to work with us to enhance the overall scientific return from our programs.

Other nations no longer must depend on the United States for access to space. A number of Western nations now have indigenous spacecraft and/or launch capabilities. As a result, NASA maintains an active dialogue with space agencies abroad to exchange information on our respective plans and to identify potential areas for cooperation. We will not only continue our past practice of inviting foreign participation in NASA missions, but we will also seek opportunities to participate in the missions of other nations and to jointly define missions of mutual interest. In addition to working with developed nations that have well-established space capabilities, NASA also conducts cooperative projects with developing nations. An area that is particularly attractive for participation by developing nations is Earth observations, especially the provision of ground-truth data.

OSSA is strongly committed to fulfilling existing international cooperative agreements with traditional major space partners in Western Europe, Canada, and Japan. In many cases, foreign contributions to NASA space science missions currently under development are quite significant. For example, the Hubble Space Telescope to be launched in 1990 involves major scientific hardware contributions by the European Space Agency (ESA); the Gamma Ray Observatory will carry one European instrument in its four-instrument payload; and the Advanced X-ray Astrophysics Facility will carry a Dutch instrument. The Ocean Topography Experiment (TOPEX/POSEIDON) is being carried out as a joint development effort with France, and the Upper Atmosphere Research Satellite involves investigators from Canada, the United Kingdom, France, and the Federal Republic of Germany, in addition to U.S. investigators. The Galileo mission currently en route to Jupiter uses a Federal Republic of Germany retro propulsion system on the U.S.-developed orbiter spacecraft. The Tropical Rainfall Measurement Mission is planned as a cooperative effort with Japan. The NASA Scatterometer and the Total Ozone Mapping Spectrometer are planned to fly on the Japanese Advanced Earth Observations Satellite. The International Solar-Terrestrial Physics program, a multilateral coordinated program to study interactions in the Sun-Earth system, will involve contributions of spacecraft from Japan (the Geotail mission) and ESA (the SOHO and Cluster missions), in addition to the two-spacecraft contribution of NASA (the Wind and Polar missions). The multilateral "Inter-Agency Consultative Group on Space Science," composed of space agencies of Europe (ESA), Japan (ISAS), the Soviet Union (Intercosmos), and the U.S. (NASA), serves to coordinate the various International Solar-Terrestrial Physics missions with planned Soviet missions in this area of scientific inquiry. The International Microgravity Laboratory is an example of a major NASA Spacelab mission series in which the U.S. and its international partners play cooperative roles.

The Earth Observations International Coordination Working Group is the forum within which the U.S., Europe, Japan, and Canada discuss, plan, and negotiate international cooperation on the Earth Observing System. The delegations are led by the Earth observations offices of these nations' respective space agencies and also include operational environmental monitoring agencies. The group meets three to four times annually to address a full range of technical and policy issues that include payload, operations, data management and policy, and instrument interfaces.

The intent of the small-class Explorer program of focused-science missions using Scout-class expendable launch vehicles is to eventually achieve two launches per year, including launches designated for U.S. scientific missions and others for foreign missions. In exchange for the U.S.-provided launch, opportunities for U.S. scientists to fly experiments on foreign spacecraft will be made available. The small Explorer program should ultimately provide new opportunities for those nations with space science programs that are more modest in scale.

OSSA's upcoming missions in planetary science—the CRAF/Cassini missions—entail substantial participation from the Federal Republic of Germany (CRAF) and ESA (Cassini). In 1989, NASA and ESA issued simultaneous coordinated AOs for the Cassini Saturn Orbiter and the Huygens Probe. The OSSA initiative proposed for FY 1991—EOS—is being planned as a major cooperative venture between the U.S., ESA, and Japan, with additional participation by other Western nations. Discussions are also in progress regarding possible Federal Republic of Germany and Italian collaboration on the Orbiting Solar Laboratory and Federal Republic of Germany collaboration on SOFIA. Opportunities for cooperation involving the flight of U.S. investigations on foreign missions will also continue to arise, and OSSA will seek to provide adequate resources to retain the flexibility to take advantage of these opportunities.

NASA has worked with the Soviet Union in space science activities since the early 1960s. With the signing of the most recent U.S./U.S.S.R. Space Cooperation Agreement in 1987, a new era of bilateral space science cooperation has been initiated. OSSA is engaged in implementing an increasingly active and ambitious program of joint activities with the Soviet Union; those activities are carried out on the basis of scientific merit, mutual benefit, and reciprocity. To that end, five Joint Working Groups have been established and meet annually to review the progress of ongoing projects and to propose new science activities: space biology and medicine, solar system exploration, solar-terrestrial physics, astronomy and astrophysics, and Earth science. Joint activities under this agreement initially included exchanges of data, scientific personnel, and mission coordination/

optimization. For example, U.S. scientists were jointly selected as "participating scientists" in the Soviet Phobos mission. Soviet scientists participated in the Voyager Neptune encounter in August 1989, and they will participate in the Magellan mission as well. Looking to the future, we intend to jointly select another group of U.S. scientists to be "participating scientists" in the U.S.S.R.'s Mars '94 mission, and to select a group of U.S.S.R. participating scientists on the 1992 Mars Observer mission.

During the May-June 1988 Moscow Summit, the U.S./U.S.S.R. space agreement was expanded to include two new project areas: (1) the exchange of opportunities for flight of scientific instruments on one another's spacecraft, and (2) the exchange of results of independent national studies of future robotic solar system exploration missions as a means for assessing the prospects for future U.S./U.S.S.R. cooperation on such missions. Both nations also agreed at that time to increase the level of exchange of scientific personnel and scientific data within the framework of the U.S./U.S.S.R. space agreement.

We are currently engaged in implementing a project involving a 1991 flight of the U.S. Total Ozone Mapping Spectrometer instrument on a U.S.S.R. Meteor-3 satellite, and the Soviets are preparing a gamma ray burst detector to fly on the Wind spacecraft in 1992. In addition, we are preparing two high-energy astrophysics instruments for flight on the U.S.S.R.'s 1993 Spectrum-X Gamma mission: an X-ray polarimeter and an all-sky monitor. The U.S. is now planning to participate in the Soviet Radioastron mission; NASA will provide ground-based communications support to the spacecraft. We are also in the midst of modifying our 1992 U.S. Mars Observer spacecraft to receive a Soviet-provided receiver (built by the French) to serve as a communications relay for the Soviet Mars '94 balloon mission. Exchanges of study results have taken place on the following proposed missions: Solar Probe, Mercury Orbiter, and Mars Rover/Sample Return.

In space biology, OSSA will play a major role in the Soviet 1992 COSMOS Biosatellite mission. The United States will also conduct medical pre-, in-, and post-flight investigations with cosmonauts on the MIR space station. These studies will be initiated in 1990 and will expand over the next few years as both nations collaborate on joint biomedical studies of flight crews on both MIR and Space Shuttle missions.

In all our interactions with the Soviets, OSSA is making a transition to a traditional working relationship in which principles of open competition and scientific peer review are being used to respond to Soviet invitations for flight opportunities or joint data analysis activities. Although we are pleased with the progress being made in developing our cooperative relationship in space science with the Soviet Union, the pace at which these efforts proceed in the future will depend, in part, on the availability of resources to support an expanding cooperative program.

APPENDIX: THE OSSA SCIENTIFIC DISCIPLINES—INDIVIDUAL STRATEGIES

Developing a strategy for the future program of OSSA and its discipline divisions begins in the scientific research community, where active collaboration between OSSA and the community translates goals into strategies for scientific discipline programs. A number of panels of the National Academy of Sciences and the NASA Advisory Council advise OSSA about broad issues of the overall OSSA program. These panels include the Space Studies Board, the Space Science and Applications Advisory Committee, and the Aerospace Medicine Advisory Committee. These and other special advisory bodies, such as the Space Station Science and Applications Advisory Subcommittee, the Committee on Global Change, and the Exploration Science Working Group, also specifically address the composition and direction of each of the scientific disciplines that fall under OSSA's umbrella. Focused groups, such as scientific working groups and project definition teams, provide more specific recommendations regarding particular project strategies. These advisory bodies, and the publications in which their recommendations are elucidated, are listed at the end of each discipline description.

With the recommendations of these advisory groups as detailed objectives, and with the overall goals for space science and applications providing the framework, each scientific discipline formulates specific program plans designed to focus on a particular aspect of the OSSA program. Each division strives to complement the other six, and each formulates a strategy that can then be integrated into a comprehensive, cohesive plan, which provides a context for decision-making within OSSA.

In the pages that follow, we summarize for each discipline its goals and objectives, its current situation, relevant factors of the external environment, and the strategy that will guide its activities for the next 5 to 10 years. The integration of these individual plans is the basis of OSSA's overall strategy.

Astrophysics

The astrophysics program uses space missions in Earth orbit and, perhaps, ultimately on the Moon, to observe the universe and develop physical models of the phenomena observed. The program is implemented in close coordination with the astronomical community, especially through the cognizant committees of the National Academy of Sciences.

The goals of the program relate to three key themes—cosmology, astronomy, and physics—to address the questions:

What was the origin of the universe? What is its large-scale structure? What will be its fate?

What is the origin of galaxies, stars, planets, and life, and how do they evolve?

What is the physics of matter under the extreme conditions found in astrophysical objects?

The program is optimized around a methodology that first includes contemporaneous observations across the entire electromagnetic spectrum. The "Great Observatories" are major missions covering the four major wavelength bands—infrared, ultraviolet/visible, X-ray, and gamma-ray. Explorer, Spacelab, Space Station Freedom, and suborbital missions bridge the gaps in the measurements made by the Great Observatories.

Second is the provision of data to, and data analysis by, the science community through an infrastructure including the Astrophysics Data System, Directory Service, workstations, and software; and grants for data analysis, supported by theory, laboratory astrophysics, ground-based telescope data, and education initiatives. The third element is investment in long-term viability via a continuing series of short time scale flight opportunities using aircraft, rockets, balloons, and moderate and small-sized Explorer satellites.

CURRENT SITUATION

The Great Observatories program is progressing well. The Hubble Space Telescope and the Gamma Ray Observatory will be launched in 1990. The Advanced X-ray Astrophysics Facility is moving forward with primary emphasis on the fabrication of its flight mirrors. The Space Infrared Telescope Facility is entering development and planning for a new start in 1993. Each of these missions is an enormous advance over its predecessor, and together they promise a revolution in our understanding of the beauty and complexity of the universe.

Explorer and Spacelab activities are highlighted by the launch and successful early operations of the Cosmic Background Explorer. The International Ultraviolet Explorer will enter its thirteenth operational year. More than 1,000 astronomers have made observations with this instrument. Among the Spacelab activities, exploration into the far ultraviolet and X-ray bands will occur with the launch of the Astro mission within the Shuttle cargo bay.

The Roentgen Satellite, in cooperation with the Federal Republic of Germany, will be launched in 1990 on a Delta-II rocket. The Extreme Ultraviolet Explorer remains on track for a 1991 launch, and work is underway on the X-ray Timing Explorer. Both these missions will use the Explorer Platform.

STRATEGY TO BE PURSUED FOR THE NEXT 5-10 YEARS

The Hubble Space Telescope and the Gamma Ray Observatory will continue operations after their 1990 launches. Starting in 1996, the original instruments on the Hubble Space Telescope will be replaced by an infrared array camera and a "two-dimensional" ultraviolet spectrograph. The Advanced X-ray Astrophysics Facility is planned for a 1997 launch. The Space Infrared Telescope Facility is planned for development and launch by the end of the century.

In addition to the Great Observatories, both moderate and small Explorer missions are under development or in planning. The Far Ultraviolet Spectroscopy Explorer, the third payload for the Explorer Platform, is planned for installation by the Space Shuttle during 1997. A small-sized Explorer mission, the Submillimeter Wave Astronomy Satellite, will begin development in FY 1991, with plans for completion and launch during the summer of 1993.

Planning is underway for an Explorer mission to study nuclear emission line sources in the galaxy and beyond. The Nuclear Astrophysics Explorer would provide the first high spectral resolution survey of gamma ray sources in the energy range of 0.05 to 10 MeV. Planning is also underway for a moderate mission, the Submillimeter Infrared Line Survey Mission, which will target about 100 to 200 sources for a complete spectral line survey, at high spectral resolution, in the 100 to 1,000 micron region.

Work continues on international collaborations as part of the Explorer Program. U.S. instruments will be flown aboard the Japanese Solar-A and Astro-D missions scheduled to be launched during 1991 and 1993 respectively. In 1994, Japan will launch the Infrared Telescope in Space as part of the instrument complement on the Space Flyer Unit mission. One of the four focal plane instruments on this telescope is being developed by the U.S., and a second instrument is being developed jointly by the U.S. and Japan. U.S. X-ray astronomy instruments will also be part of the Soviet Spectrum-X-Gamma Mission and the European Space Agency's X-Ray Multi-Mirror Mission.

Another international collaboration is the Stratospheric Observatory For Infrared Astronomy (SOFIA) project with the Federal Republic of Germany. The SOFIA project will mount an advanced infrared/submillimeter telescope on a modified Boeing 747 aircraft to significantly enhance our current suborbital observing capabilities to complement the Great Observatories and offer essential opportunities for training new scientists and instrumentalists.

Two international cooperative space Very Long Baseline Interferometry missions are being planned with the Soviets and the Japanese. Both missions will use satellites with 10-meter diameter radio telescopes to obtain orbital radio astronomical signals. Correlation with ground observations will produce angular resolution of tens of microarcseconds.

Development of an active astrophysics element of the Space Exploration Initiative is currently under way. Low gravity, lack of atmosphere, seismic stability, large dimensions, and the availability of virtually unlimited amounts of lunar rock for radiation shielding make the Moon a most promising site for an astronomical observatory. The selection of potential astrophysical instruments is based on scientific merit, relevance of the Moon as a site, and cost-effectiveness. Current plans envision an evolutionary progression of instruments. For example, the progression could begin with a 1- to 2-meter ultraviolet/visible/near infrared lunar transit telescope. This could be followed by the installation of various wavelength interferometers. The series could culminate with the installation of a 16-meter filled aperture segmented optical telescope. These and other instruments will be studied in the future for their potential application to the lunar outpost.

ADVISORY COMMITTEES AND RELEVANT REPORTS

Committee on Space Astronomy and Astrophysics of the Space Science Board, National Academy of Sciences, National Research Council

The Explorer Program for Astronomy and Astrophysics (1986).

Long-Lived Space Observatories for Astronomy and Astrophysics (1987).

Astronomy and Astrophysics Survey Committee, National Academy of Sciences, National Research Council

Astronomy and Astrophysics for the 1990s (target availability 1991).

Solar System Exploration

The fundamental goals and approaches of the solar system exploration program are those recommended by the Committee on Planetary and Lunar Exploration of the National Academy of Sciences and the Solar System Exploration Committee of the NASA Advisory Council. Briefly stated, the goals are:

Origin and Evolution: To determine the present nature of the solar system, its planets, moons, and primitive bodies, and to search for other planetary systems in various stages of formation, in order to understand how the solar system and its objects formed, evolved, and (in at least one case) produced environments that could sustain life.

Comparative Planetology: To better understand the planet Earth by determining the general processes that govern all planetary development and by understanding why the "terrestrial" planets of the solar system are so different from each other.

Pathfinders to Space: To establish the scientific and technical data base required for undertaking major human endeavors in space, including the survey of near-Earth resources and the characterization of planetary surfaces.

Solar system exploration is conducted in three distinct stages: (1) reconnaissance, involving flyby missions; (2) exploration, generally conducted with orbiting spacecraft and atmospheric probes; and (3) intensive study, involving soft landers, sample returns, and human exploration. The essential part of this exploration is a Core Program of balanced missions and research that stresses continuity, commonality, cost-effectiveness, and the use of existing technology. This program consists of: (1) moderate-scale Planetary Observer missions to the inner planets, using previously developed spacecraft equipment; (2) Mariner Mark II missions to the outer planets, using common spacecraft and evolving technology; (3) development of a multimission spaceflight operations and data analysis capability; and (4) a strong program of ground-based research and analysis and related activities. An Augmented Program includes more complex and sophisticated candidate missions: robotic sample returns from a comet and from the surface of Mars, and the beginning of the search for planetary systems around other stars.

CURRENT SITUATION

The successful Voyager 2 encounter with Neptune in August 1989 virtually completed the reconnaissance phase of solar system exploration. With the exception of Pluto, all the planets and most of the larger moons have been studied by spacecraft at close range. Also in 1989, the exploration phase advanced with the launches of the Magellan radar mission to map Venus and the Galileo orbiter/probe mission to Jupiter. Exploration will continue with the 1992 launch of the Mars Observer to complete a global scientific assessment of Mars and with the launch of two newly approved missions in the mid-1990s: CRAF to an asteroid and comet and Cassini to the planet Saturn.

Other nations—particularly the U.S.S.R., Western Europe, and Japan—have now established robust and ambitious programs of solar system exploration. The presence of these other programs has already generated specific cooperative and collaborative efforts involving Galileo, Mars Observer, CRAF, and Cassini, and we expect that such cooperative activities will expand in the future.

STRATEGY TO BE PURSUED FOR THE NEXT 5-10 YEARS

The highest priority for solar system exploration is to complete those missions now launched or under development, which will preserve U.S. preeminence in the exploration of both the inner and outer solar system and will, in particular, initiate a program of excellence in the study of comets and asteroids. Beyond these missions, the Solar System Exploration Division, in close cooperation with the science community, is now developing a flexible, dual-path strategy for the exploration of the solar system in the 1990s and beyond. The first path continues and expands the traditional scientific program; the second path responds to a national commitment for human exploration of the Moon and Mars. In the traditional path, the Lunar Observer would be the next mission, followed by such missions as a Mars surface network and orbiter/probe missions to the outer planets beyond Saturn. This dual program has the advantage of flexibility because, in the near term, the "traditional" path is identical to the one for human exploration. However, the second path would, after the Lunar Observer, carry out additional detailed exploration and characterization of Mars by means of landed networks, imaging orbiters, sample returns, and rovers. Planning is also under way for a "Discovery" program of small missions in planetary science.

In any active program of solar system exploration, Space Station Freedom will play a significant role. Two candidate attached payloads are under active consideration: a Cosmic Dust Collection Facility, which would collect particles of cosmic dust for analysis back on Earth, and a possible telescope facility for detecting and characterizing planetary systems around other stars.

Current plans for solar system exploration place a high priority on launch and mission risk reduction. A policy has been established with the Mars Observer and CRAF/Cassini missions to acquire spare key subsystem components in order to enable rapid changeout during development testing. This approach will protect the development schedule and the launch windows; if the spares are not needed, they can provide a cost-effective nucleus for a subsequent mission. Future mission planning will also provide for backup in case of major mission failure.

Solar system exploration must remain at the cutting edge of space science and space technology, and the research and analysis base is being enhanced to support crucial advanced technology development, advanced mission studies, and related science initiatives. Two enhancements to the research base—for instrument and laboratory upgrading and for an interdisciplinary "Origins of Solar Systems" initiative—were provided in FY 1990. A potential science initiative now being studied—"Comparative Planetology"—would take advantage of the data from new missions to the inner solar system (Magellan, Mars Observer, Lunar Observer, and the partially successful U.S.S.R. Phobos mission) and from the planned Earth Observing System to deepen our understanding of planet Earth by studying the detailed differences between the inner planets.

ADVISORY COMMITTEES AND RELEVANT REPORTS

Committee on Planetary and Lunar Exploration of the Space Science Board, National Academy of Sciences, National Research Council

- *Strategy for Exploration of Primitive Solar-System Bodies—Asteroids, Comets and Meteoroids: 1980-1990* (1980).
- *A Strategy for Exploration of the Outer Planets, 1986-1996* (1986).
- *Advanced Instrumentation for Planetary Exploration* (in press).
- *A Strategy for the Detection of Extra-Solar Planetary Material* (target availability, 1990).

Joint Working Group of the National Academy of Sciences and the European Science Foundation, National Research Council

- *Report of the NAS/ESF Joint Working Group: A Strategy for U.S.-European Cooperation in Planetary Exploration* (1986).

Solar System Exploration Committee of the NASA Advisory Council

- *Planetary Exploration through Year 2000: Part One: A Core Program* (1983).
- *Planetary Exploration through Year 2000: Part Two: An Augmented Program* (1986).
- *Planetary Exploration through Year 2000: Scientific Rationale* (1988).

The Planetary Astronomy Committee of the Solar System Exploration Division

- *Other Worlds from Earth: The Future of Planetary Astronomy* (1989).

Space Physics

The space physics program investigates the origin, evolution, and interactions of space plasmas in a wide variety of astrophysical settings. The goal of the discipline, endorsed by the Committee on Solar and Space Physics of the National Academy of Sciences, is to understand:

The Sun, both as a star and as the dominant source of energy, plasma, and energetic particles in the solar system,

The interactions between the solar wind and solar system bodies, including studies of the ionospheres and magnetospheres of the Earth and other solar system bodies,

The nature of the heliosphere, in its steady state as well as dynamic configuration, and

The origin, acceleration, and propagation of solar and galactic cosmic rays.

Data are obtained by probes situated within plasma systems, such as a magnetosphere or the heliosphere. Remote sensing is used for inaccessible regions, such as the solar surface, and regions requiring a global view, such as Earth's auroral zone. Cosmic rays provide a means of studying phenomena outside our solar system. These measurements are obtained by instruments mounted on free-flying satellites, the Space Shuttle, sounding rockets, and balloons. Researchers use theory, models, and computer simulations to synthesize these measurements into a general understanding of space physics phenomena.

CURRENT SITUATION

Initial reconnaissance of a variety of solar system magnetospheres and ionospheres, of the heliosphere itself, and of the layers of the solar atmosphere has nearly been completed, and solar and galactic cosmic rays have been characterized. Many phenomena have been identified and classified, and some understanding of cause-and-effect relationships has been established.

Three U.S. spacecraft continue to collect scientific information: the International Cometary Explorer, Interplanetary Monitoring Platform, and Dynamics Explorer. Coordinated plasma physics studies are being conducted jointly among Japan (Akebono), the Soviet Union (ACTIVE), and the U.S. (Dynamics Explorer).

The DoD/NASA Combined Release and Radiation Effects Satellite, to be launched in 1990, will map the radiation belts during the solar maximum and conduct further studies of ionosphere/magnetosphere interactions through the analysis of chemical releases. Augmenting these investigations is analysis of chemical releases from Pegsat. Also to be launched in 1990, the ESA/NASA Ulysses mission will study the heliosphere out of the ecliptic plane. The U.S./Italian Tethered Satellite System (1991), which will carry a diagnostic satellite tethered to the Space Shuttle by a 20-kilometer conducting wire, will investigate electrodynamic plasma effects. Further measurements of the Sun will be made with the Spartan-201 white light coronagraph and UV coronal spectrometer and with X-ray instruments planned for the Japanese/U.S. Solar-A mission.

The next major flight program is the International Solar Terrestrial Physics program, consisting of the Global Geospace Science program and the ESA Solar Terrestrial Science Programme. The Global Geospace Science program, which will investigate geospace as an interconnected interactive system, includes the NASA Wind and Polar satellites, the Japanese/NASA Geotail mission, and the Combined Release and Radiation Effects Satellite extended mission phase. The Solar-Terrestrial Science Programme includes the Solar and Heliospheric Observatory and Cluster missions, both of which will feature NASA-contributed instruments.

Two small-class Explorers, the Solar, Anomalous, and Magnetospheric Particle Explorer and the Fast Auroral Snapshot Explorer, are in development for launches in 1992 and 1993. Also approved for addition to the Delta-class Explorer program is the Advanced Composition Explorer.

STRATEGY TO BE PURSUED FOR THE NEXT 5-10 YEARS

The health of the space physics discipline depends on maintaining a mix of major, moderate, and small missions, the suborbital program, and modest increases in support of the research base. The highest priority major mission is the Solar Probe, which will make humanity's first in situ measurements in the near vicinity of the Sun. The highest priority moderate mission is the Orbiting Solar Laboratory. Its unique ability to investigate the Sun's fine-scale magnetic structure will contribute to important scientific objectives, and it may lead to the capability to predict solar particle events, which pose a threat to human travelers occupied in exploring the Moon or Mars. The planned 1997 launch of the Orbiting Solar Laboratory makes it an ideal prelude to a system of monitoring stations to form a warning network in support of human exploration missions.

A small-class payload using chemical releases to study ionospheric chemical and electrodynamical processes in conjunction with the Combined Release and Radiation Effects Satellite is the highest priority small mission. Many objectives can be fulfilled through other small programs, such as Explorers, sounding rockets and balloons, and Space Shuttle-attached payloads. Small payloads attached to spacecraft with other primary missions can be utilized to study space plasma processes. Future small and rapid-response Space Station Freedom opportunities also can provide important focused science results and essential training opportunities for graduate students. An important candidate Space Station Freedom attached payload facility is the superconducting Astromag system, which can study galactic cosmic rays of GeV to TeV energies. A significant opportunity for the study of the dynamics and structure of the heliosphere is offered by the coordination of the ongoing International Cometary Explorer, Interplanetary Monitoring Platform, Pioneers 10 and 11, and Voyagers 1 and 2, as well as by the upcoming Ulysses, Mars Observer, and Galileo missions.

A feasibility study is nearing completion for a Mercury orbiter mission to provide measurements of the solar wind interaction with the magnetized planet and to complete the mapping of the planet's surface.

The international space physics community is moving toward an unprecedented level of cooperation in solar-terrestrial science in the 1990s that will include major U.S. collaborations with European, Japanese, and other allies, and a number of projects and joint studies that are going forward under the auspices of the U.S./U.S.S.R. Joint Working Group on Solar Terrestrial Physics.

ADVISORY COMMITTEES AND RELEVANT REPORTS

Committee on Solar and Space Physics of the Space Science Board, National Academy of Sciences, National Research Council

Solar-System Space Physics in the 1980s: A Research Strategy (1980).

Solar-Terrestrial Research in the 1980s (1981).

An International Discussion on Research in Solar and Space Physics (1983).

A Strategy for the Explorer Program for Solar and Space Physics (1984).

Solar-Terrestrial Data Access, Distribution, and Archiving (1984).

The Physics of the Sun (1985).

An Implementation Plan for Priorities in Solar-System Space Physics (1985).

Committee on Solar-Terrestrial Research of the Space Science Board, National Academy of Sciences, National Research Council

National Solar-Terrestrial Research Program (1984).

Long-Term Solar-Terrestrial Observations (1988).

Physics Survey Committee, National Academy of Sciences, National Research Council

Physics through the 1990s: Plasma and Fluids (1986).

Earth Science and Applications

The overarching goal of Earth science and applications as formulated by the Earth System Sciences Committee of the NASA Advisory Council is to:

Obtain a scientific understanding of the entire Earth system on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve on all time scales.

Study of phenomena in Earth's atmosphere, oceans, on land, and within the biosphere must be directed at understanding the responsible physical, chemical, and biological processes that operate to unify the Earth environment as a system. These processes must then be cast in the form of algorithms for assimilation into global models. Finally, these models must be tested against comprehensive, long-term global-scale data sets in order to validate their accuracy as descriptive and predictive tools.

CURRENT SITUATION

The Division is currently planning for a major new start in FY 1991 on EOS, which will provide the core elements of Mission to Planet Earth: two polar platform series and their science instruments, the EOS Data and Information System, and duplicate EOS payloads attached to Space Station Freedom. Together with the Earth Probes new start for FY 1991, EOS will provide the long-term, global-scale, self-consistent data sets required for understanding and predicting global change.

Current flight programs include the Nimbus-7 research satellite currently returning global ozone data; the Earth Radiation Budget Experiment to measure the global energy balance that is so important to climate and global change; the Upper Atmosphere Research Satellite, which will study the chemistry and dynamics of the stratosphere and mesosphere important for the ozone layer; the Ocean Topography Experiment (TOPEX/POSEIDON), a joint project with France that will map the global circulation of the oceans; the NASA Scatterometer and a Total Ozone Mapping Spectrometer to fly on the Japanese Advanced Earth Observations Satellite for measurement of the wind stress that drives ocean currents and couples the atmosphere to the sea; the LAGEOS II laser geodynamics satellite joint project with Italy for measuring crustal motions; RadarSat, a joint project with Canada in which the U.S. will launch a Canadian radar satellite for polar ice and snow studies; and the Total Ozone Mapping Spectrometer, to fly on a Soviet meteorological satellite in 1991.

The Total Ozone Mapping Spectrometer is also the first in the proposed line of Earth Probes, an Explorer-class line of missions, which will carry out observations to complement EOS with measurements that cannot be carried out from polar orbit. Current plans include additional flights of the Total Ozone Mapping Spectrometer instrument on U.S., Japanese, and Soviet spacecraft; a Tropical Rainfall Measurement Mission; the Proteus Ocean Productivity Experiment; a Magnetic Field Explorer; and a Solid Earth Mission.

In addition, several Shuttle payload missions are planned, including the Shuttle Solar Backscatter UltraViolet instrument for atmospheric ozone sounding, the Atmospheric Laboratory for Applications and Science for measuring the solar output and the chemistry and dynamics of the atmosphere, and the Space Radar Laboratory for Earth remote sensing and imaging. The foundation for Earth science space-borne instruments is the Division's aircraft and Shuttle payloads development program. The aircraft observation program is used to support field experiments on Earth system process studies and for instrument development. The Division continues to develop and launch NOAA's polar-orbiting and geostationary environmental satellites.

STRATEGY TO BE PURSUED FOR THE NEXT 5-10 YEARS

The long-term strategy for the Earth Science and Applications Division has been defined by the Earth System Science Committee in combination with the recent definition of the U.S. Global Change Research Program by the Committee on Earth Science to focus on three objectives: (1) establish an integrated, comprehensive monitoring program for Earth system measurements on a global scale; (2) conduct a program of focused studies to improve our understanding of the physical, chemical, and biological processes that influence Earth system changes and trends on global and regional scales; and (3) develop integrated conceptual and predictive Earth system models.

To achieve the first goal, the Division has devised the concept of Mission to Planet Earth, an architecture for global Earth observations involving four elements: the Earth Observing System of polar orbiting platforms, payloads attached to Space Station Freedom, a series of Earth probes, and a set of geostationary orbiting platforms. The second and third goals require the reorganization of the Division into interdisciplinary elements in Earth system process studies for understanding of the Earth, more focused effort on constructing models of the Earth as a global system, and the construction of a data and information system for easy access to global space-based Earth remote-sensing data.

The first steps in this strategy have been taken in this past year. First, the Division has been reorganized along interdisciplinary research lines and into four main elements to match the stated objectives: two Flight Program elements (EOS is treated as a single program element) to provide for global scale observations and monitoring, Modeling and Data Analysis to provide for the construction of Earth system models and EOSDIS as the principal element of a data and information system for global scale Earth observation data, and Earth System Process Studies for basic research to understand how the Earth functions as a global system. The second major step is the proposal of the core elements of Mission to Planet Earth as a new start in the FY 1991 budget.

One essential element of EOS was not proposed for an FY 1991 new start, the EOS Synthetic Aperture Radar (EOS SAR) spacecraft, and will require a new start in the FY 1994-1995 time frame. The EOS mission is not complete without the SAR, which is required for surface geological studies and for understanding the global carbon cycle. Planning is underway for the EOS SAR and for the final element of Mission to Planet Earth: the Geostationary Platforms. Geostationary Platforms are required for observation of processes that have large diurnal variation, and others such as precipitation, which occur only during short periods of time, and therefore cannot be properly sampled from polar orbiting platforms.

ADVISORY COMMITTEES AND RELEVANT REPORTS

Committee on Global Change, National Academy of Sciences

Toward an Understanding of Global Change: Initial Priorities for the U.S. Contribution to the International Geosphere Biosphere Program (1988).

Committee on Earth Sciences, Federal Coordinating Committee on Science, Engineering and Technology, Office of Science and Technology Policy

Our Changing Planet: The FY 1990 Research Plan (1989).

Our Changing Planet: The FY 1991 U.S. Global Change Research Program (1990).

Earth System Sciences Committee of the NASA Advisory Council

Earth System Science: A Program for Global Change (1986).

Committee on Earth Sciences of the Space Science Board, National Academy of Sciences, National Research Council

A Strategy for Earth Science from Space in the 1980s. Part I: Solid Earth and Oceans (1982).

A Strategy for Earth Science from Space in the 1980s. Part II: Atmosphere and Interactions with the Solid Earth, Oceans, and Biota (1985).

Strategy for Earth Explorers in Global Earth Sciences (1988).

Life Sciences

The life sciences discipline is involved in all aspects of NASA's activities in space exploration. The program has four major goals:

Ensure the health, well-being, and productivity of humans in space.

Develop an understanding of the role of gravity on living systems in space.

Expand our understanding of the origin, evolution, and distribution of life in the universe.

Promote the application of life sciences research to improve the quality of life on Earth.

The life sciences program extends from fundamental biological research using the spaceflight environment to applied clinical practice with two principal themes: (1) basic scientific research in biomedical physiology, space biology, biospherics, and exobiology; and (2) enabling technology definition, development, and operational implementation of medical support and life support systems for human spaceflight.

Earth-based laboratory research, conducted in NASA laboratories and in extramural programs centered on university-based individual Principal Investigators and Specialized Centers of Research and Training, is combined with on-orbit basic and applied research that utilizes the spaceflight environment as an experimental tool to study basic processes on a variety of animal and plant species, as well as human beings. The exobiology and biospherics elements of the program use planetary exploration spacecraft and Earth observing systems, in addition to ground-based studies, to understand the processes that led to the origin of life and to study the continuing interplay between planetary environments and living processes.

The Life Sciences Division is responsible for providing the requirements, practices, and procedures for medical, environmental, and operational life support, medical support, and extravehicular activity systems for the Space Shuttle, Space Station Freedom, and Space Exploration Initiative missions. The Division also defines the specific mission requirements for medical support and life support, conducts ground-based and flight research necessary to specify design criteria and establish operational protocols and procedures, and performs implementation monitoring to ensure that mission designs meet human life support requirements.

CURRENT SITUATION

Efforts have been initiated to implement the recommendations of advisory panels to upgrade the ground-based research infrastructure, provide life support technology for the Agency, and expand the flight capabilities required by the disciplines, but these efforts continue to be constrained by limited fiscal and manpower resources.

Since much research depends heavily upon access to the spaceflight environment, the Division has implemented major flight programs that will come to fruition in the near term. A series of dedicated Spacelab missions, commencing with Spacelab Life Sciences 1 in August 1990 and continuing at the rate of one dedicated mission every 2 years, represents the first opportunity since Skylab to collect systematic experimental data on primary physiological systems. This series of missions is augmented with cooperative Spacelab missions with our foreign partners, and with International Microgravity Laboratory missions. In addition, the Division has an ongoing program in joint scientific studies on the Space Shuttle and utilizing the Soviet COSMOS biosatellite flights every 2 years. An active program of biomedical studies utilizing the Soviet MIR space station and U.S. Spacelab Life Sciences missions is under way.

The Division is conducting the Extended-Duration Orbiter Medical Program to ensure that Space Shuttle crews are capable of safely landing and leaving the Shuttle after 13- to 16-day missions. The program monitors cardiovascular and neuromuscular performance capabilities and provides appropriate countermeasures to maintain crew capability within established limits, with the goal of medically certifying the extended duration operations by the time of the first U.S. Microgravity Laboratory flight.

NASA Specialized Centers of Research and Training are being established to mobilize university-based talent to concurrently advance basic knowledge and generate effective strategies to solve specific problems in focused life science areas. The three initial areas are gravitational biology, environmental health, and bioregenerative life support, and will draw together research and training expertise in these selected areas, providing a stable base upon which problem-solving strategies can be built. In addition, the ground-based SETI Microwave Observing Project has been implemented to search for radio signals from distant technologies, and the observation phase should last from 1992 to 1999.

STRATEGY TO BE PURSUED FOR NEXT 5-10 YEARS

The Division will continue to increase its access to spaceflight with extended exposure durations. Dedicated 13-day Spacelabs are scheduled for 1992 with potential mission operations of up to 16 days by 1994. Both dedicated Spacelab and International Microgravity Laboratory missions are planned to continue in extended duration mode until Space Station Freedom capabilities permit significant on-orbit research. The Lifesat biosatellite has been defined to enable space-based quantitative studies of biological effects of the unique spectrum of space radiation and to provide additional flight opportunities in basic biological research. Lifesat can enter orbits chosen to meet the scientific requirements, including the polar orbits of interest to radiation biology, and can provide autonomous return from flights of up to 60 days. Current plans call for two flight opportunities per year.

Space Station Freedom offers another unique opportunity for the development of international leadership in life sciences research. The on-orbit Space Station Freedom facilities will focus on basic biomedical research to understand the various mechanisms responsible for adaptation to weightlessness and the physiological problems encountered upon return to Earth. To meet Freedom operational requirements, a Biomedical Monitoring and Countermeasures program is being established to optimize physiological countermeasures. On-orbit centrifuges will provide artificial gravity to enable controlled studies with animal and plant subjects and the initiation of variable-gravity studies utilizing the unique capabilities of spaceflight research. Space Station Freedom facilities will also serve to confirm the feasibility of establishing a fully regenerative life-support system for use on future human exploration missions.

ADVISORY COMMITTEES AND RELEVANT REPORTS

Committee on Space Biology and Medicine of the Space Science Board, National Academy of Sciences, National Research Council

Life Beyond the Earth's Environment—The Biology of Living Organisms in Space (1979).

A Strategy for Space Biology and Medical Science for the 1980s and 1990s (1987).

Committee on Planetary Biology and Chemical Evolution of the Space Science Board, National Academy of Sciences, National Research Council

Origin and Evolution of Life—Implication for the Planets: A Scientific Strategy for the 1980s (1981).

Planetary Biology and Chemical Evolution: Progress and Future Directions (target availability, 1990).

Committee on Planetary Biology of the Space Science Board, National Academy of Sciences, National Research Council

Remote Sensing of the Biosphere (1986).

Life Sciences Strategic Planning Study Committee of the NASA Advisory Council

Exploring the Living Universe: A Strategy for Space Life Sciences (1988).

Microgravity Science and Applications

The microgravity science and applications program uses the unique attributes of the space environment to conduct research in three primary areas: (1) fundamental science, which includes the study of the behavior of fluids, transport phenomena, condensed matter physics, and combustion science; (2) materials science, which includes electronic and photonic materials, metals, alloys, glasses, and ceramics; and (3) biotechnology, which focuses on macromolecular crystal growth and cell science. The goals of the program are to:

Develop a comprehensive research program in fundamental sciences, materials science, and biotechnology, for the purpose of attaining a structured understanding of gravity-dependent physical phenomena in both Earth and non-Earth environments.

Foster the growth of an interdisciplinary research community, united by shared goals and resources, to conduct research in the space environment.

Encourage international cooperation for the purpose of conducting research in the space environment.

Utilize a permanently manned, multi-facility national microgravity laboratory in low Earth orbit to provide a long-duration, stable microgravity environment.

Promote industrial application of space research for the development of new, commercially viable products, services, and markets resulting from research in the space environment.

CURRENT SITUATION

The microgravity program uses an evolutionary approach to conducting research in the environment of space. The process starts with new ideas arising from university, NASA, other Federal agencies, or industry research. These new ideas undergo a concept feasibility stage and detailed laboratory investigations to mature the hypotheses and ensure their worthiness for low-gravity flight investigations. Hypotheses are confirmed, and the flight apparatus is validated using ground-based reduced-gravity facilities. Reduced-gravity test environments of varying durations are available: up to 5 seconds in drop towers and tubes, 30 seconds in aircraft, and up to 15 minutes in sounding rockets. To cost-effectively support those investigations requiring longer periods of reduced gravity, the microgravity flight program uses a broad base of available carriers and carrier resources including the Space Shuttle Orbiter with its mid-deck, cargo pallet, Spacelab, and Get Away Special Canisters.

Microgravity payloads are scheduled for flight as mid-deck experiments on a number of Shuttle missions in 1990. The major near-term opportunities for microgravity science and applications payloads are the International Microgravity Laboratory (IML) flights, the U.S. Microgravity Laboratory (USML) flights, and the U.S. Microgravity Payload (USMP) flights. Space Station Freedom represents a significant advance in the capability to conduct microgravity research, particularly with respect to experiment duration and flexibility. Six multi-user microgravity facilities are being defined for use on Space Station Freedom. Precursor apparatus flown on the Space Shuttle will provide experience with operations and development of instrumentation and subsystems for use in the space facilities.

An Announcement of Opportunity (AO) issued in 1988 invited investigators to propose experiments using the Space Shuttle. Selection of investigations on USML-1 and IML-2 occurred in 1989. In the future, invitations such as the AO and NASA Research Announcement will be used extensively to continue to obtain high-quality science investigations.

STRATEGY TO BE PURSUED FOR NEXT 5-10 YEARS

The microgravity science and applications program supports ground-based research to prepare for flight investigations. Many ground-based efforts have matured to the point where Shuttle flights are warranted. Four flights each of USML, IML, and USMP are planned over the next 5 years. Given this substantial number of flight opportunities, renewed program focus on expansion of the ground-based research program, including the addition of sounding rocket investigations and enhanced advanced technology development is crucial, as is the development of flight hardware. Also, the development of methodology and processes for analyzing, documenting, and archiving the flight data is essential to the accomplishment of the overall program goals. The following steps will be taken to ensure optimum use of flight opportunities:

Identify and pursue high quality science investigations requiring the reduced gravity of the space environment.

Expand and facilitate an interdisciplinary research community.

Define and develop cost-effective instrument systems to conduct flight research.

Identify and pursue advanced developments to enable and enhance scientific investigations.

Develop a knowledge base of gravity dependent physical phenomena, such as fluid transfer, fire safety, and the behavior of granular media, to support human exploration of the solar system.

Develop methodology for analyzing, documenting, and archiving the flight data.

ADVISORY COMMITTEES AND RELEVANT REPORTS

Subcommittee on Microgravity Science, Applications, and Commercialization, Space Applications Advisory Committee of the NASA Advisory Council
General Program Review and Recommendations Regarding the Microgravity Centers (1987).

Microgravity Materials Science Assessment Task Force, NASA Headquarters
Microgravity Materials Science Assessment Task Force Final Report (1987).

Microgravity Science and Applications Review Committee, Universities Space Research Association
Review of Microgravity Science and Applications Programs, January-March 1987 (1987).

Task Group on Fundamental Physics and Chemistry, Space Science Board, National Research Council
Space Science in the Twenty-First Century: Imperatives for the Decades 1995 to 2015—Fundamental Physics and Chemistry (1988).

Space Station Science and Applications Advisory Subcommittee of the Space Science and Applications Advisory Committee, NASA Advisory Council
Final Report, 1988 Summer Workshop (1988).

Communications and Information Systems*

The communications research program focuses on developing the high-risk satellite and ground segment communications systems and subsystems needed to enable new services and to increase the capacity, flexibility, and interconnectivity of present and future telecommunications resources. The goals of the program are to:

Maintain U.S. leadership in space communications

Enable new and innovative services

Enhance efficient utilization of the orbital arc and electromagnetic spectrum through technology innovations

Support U.S. and NASA interests in domestic and international regulatory forums.

CURRENT SITUATION

The U.S.'s position of preeminence in space communications is being challenged by the Western European and Japanese satellite development programs, which are committed to multiple satellite developments and are used as test-beds for near- and long-term system concepts and advanced technology evaluation and demonstration. Consequently, these foreign programs will more than likely accelerate the introduction of advanced technologies into the global telecommunications market, and they may open many new and innovative services that may not be available from U.S. industry. NASA has responded to this challenge with a vigorous program that would curtail further deterioration of these assets.

The Advanced Communications Technology Satellite (ACTS) program has been the centerpiece of activities in support of U.S. industry. Scheduled for an April 1992 Shuttle deployment, ACTS technology will provide capabilities qualitatively different from those of current satellite and fiber optic systems, such as on-demand assignment, frequency reuse, and the flexible targeting of spotbeams directly to customer premises. The 2-year demonstration period will provide an opportunity for NASA to take the lead in carrying out a wide-ranging set of experiments and demonstrations to meet future commercial telecommunications needs.

COSPAS-SARSAT, a satellite-based search and rescue program, has been credited with saving more than 1,400 lives by locating distress beacons from crashed aircraft and marine vessels in distress. SARSAT evolved from NASA's research and development to become a joint venture of the U.S., Canada, and France in 1979, joined by the Soviet Union a year later. In the U.S., the program is a joint effort of the National Oceanic and Atmospheric Administration, Coast Guard, Air Force, and NASA. The constellation consists of two operational SARSAT satellites and two operational COSPAS satellites. The current ground system includes stations in ten countries, with more becoming operational in the near future. NASA is responsible for research and development activities, and will focus on development of the next spaceborne system, which will offer new services and improve system response time.

The Optical Communications program focuses on flight testing systems to support future NASA missions as well as the space demonstration of this technology to reduce its adoptive risk by the American space communications industry. This technology will both enhance and enable new science through increased data gathering, transceiving, and processing capability.

Mobile Satellite Program activities have progressed to the point where the L-band technologies have been successfully tested in true land aeronautical mobile applications. NASA's lead role in regulatory activities has significantly contributed to the securing of the L-band frequency allocation. Close cooperation between the U.S. and Canadian service providers will enable a North American mobile service by mid-1993. To meet future growth, higher frequency bands, such as Ka, are being investigated to alleviate spectrum congestion and to provide an order of magnitude increase in the user base.

*The discussion of Information Systems may be found earlier in this document; only communications research is discussed here.

Radio science experiments provide the technical basis for standards development and regulatory decisions for space services at the national and international levels. Propagation studies and measurements fill the voids in data needed for design of new satellite applications for fixed communications, mobile communications, sound broadcasting, and high definition television broadcasting. In the coming year, emphasis will be placed on the detailed characterization of Ka-band for both low and high bit rate data communications. This will be performed, in part, as a cooperative effort with the ESA Olympus I Experimenters Group as a percursor to experiments on ACTS.

STRATEGY TO BE PURSUED FOR NEXT 5-10 YEARS

Through its close partnership with industry, NASA will continue to look for opportunities to contribute to new U.S. markets and services. Emphasis will be placed on the high-risk microwave, optical, and digital subsystems needed to increase the capacity, flexibility, and interconnectivity of future systems. These developments, building on ACTS and mobile satellite technologies, will enable future satellite communication systems to provide services at lower costs to smaller terminals for both fixed and mobile commercial and scientific applications. We also plan to expand optical link developments that have the potential to greatly increase the rate of information return from deep space missions and to interconnect commercial satellite systems.

Personal access communications is a future market candidate. This system concept elevates mobile communications to its ultimate form: i.e., direct to the person two-way data and voice communications. By exploiting the advantage of high frequency bands, greater freedom of access, larger user bases, and wider diversity of services can be achieved. Key enabling technologies include: directive-tracking user antennas, multi-beam satellite antennas, MMIC/VLSI-based user terminal, rain-compensation techniques, and efficient networking technologies.

One major thrust of the communications program will be the evaluation and implementation of techniques addressing health and safety related to public sector needs. Direct support will be provided in areas in which NASA has a unique communications technology development role to address a specific, well-defined, public sector need. The Search and Rescue Satellite (SARSAT) program is such an effort. Spin-off support will be provided when public sector needs for advanced communications technology can be satisfied by technology already developed by or for NASA, or for NASA.

NASA's research and technology program will continue to be assessed with the participation of the U.S. space communications industry, so that selected high-risk enabling technologies will be identified for flight validation. Beginning in 1992, specific government and commercial flight opportunities will be identified for inclusion of these technologies on a recurring basis. These flight validation opportunities will constitute a suite of small missions consistent with the OSSA programmatic themes.

ADVISORY COMMITTEES AND RELEVANT REPORTS

Communications Subcommittee of the Space Applications Advisory Committee of the NASA Advisory Council

Communications Satellites: Guidelines for a Strategic Plan (1987).

Committee on Data Management and Computation of the Space Science Board, National Academy of Sciences, National Research Council

Data Management and Computation — Volume I: Issues and Recommendations (1982).

Issues and Recommendations Associated with Distributed Computation and Data Management Systems for the Space Sciences (1986).

Space Applications Board of the National Research Council

NASA Space Communications Research and Development: Issues, Derived Benefits, and Future Programs (1989).

OSSA Major Events Acronym List

ACTS ..... Advanced Communications Technology Satellite
Astro ..... Astronomy Laboratory
ATLAS ..... Atmospheric Laboratory for Applications and Science
BBXRT ..... Broad Band X-Ray Telescope
COBE ..... Cosmic Background Explorer
CRAF ..... Comet Rendezvous Asteroid Flyby
CRISTA ..... Cryogenic Infrared Spectrometer Telescope for Atmosphere
CRRES ..... Combined Release and Radiation Effects Satellite
EUVE ..... Extreme Ultraviolet Explorer
FAST ..... Fast Auroral Snapshot Explorer
GRO ..... Gamma Ray Observatory
HST ..... Hubble Space Telescope
HST-REV ..... Hubble Space Telescope Revisited
IML ..... International Microgravity Laboratory
LAGEOS ..... Laser Geodynamics Satellite
MSAT ..... Mobile Satellite
OMV ..... Orbital Manoeuvering Vehicle
ROSAT ..... Roentgen Satellite
SAMPEX ..... Solar, Anomalous, and Magnetospheric Particle Explorer
SL ..... Spacelab
SLS ..... Space Life Sciences laboratory
SOHO ..... Solar and Heliospheric Observatory
SPAS ..... Shuttle Pallet Satellite
SRL ..... Space Radar Laboratory
SSBUV ..... Shuttle Solar Backscatter UltraViolet instrument
STORE ..... Shuttle Test Of Relativity Experiment
SWAS ..... Submillimeter Wave Astronomy Satellite
TOMS ..... Total Ozone Mapping Spectrometer
TOPEX ..... Ocean Topography Experiment
TSS ..... Tethered Satellite System
UARS ..... Upper Atmosphere Research Satellite
USML ..... United States Microgravity Laboratory
USMP ..... United States Microgravity Payload
WISP ..... Waves in Space Plasma
XTE ..... X-ray Timing Explorer

■ Space Shuttle Launch ● Expendable Launch Vehicle Launch ▲ Other Major Events

Major Launch mode for OSSA missions purposes.

Major Events in Space Science and Applications: 1990 Planning Manifest

	January	February	March	April	May	June	July	August	September	October	November	December
1990		▲ Galileo Venus Flyby ▲ Voyager Lookback		■ HST	■ Astro/BBXRT ● ROSAT	▲ COBE completes first sky survey ● CRRES		▲ Magellan Arrives at Venus ■ SLS-1		■ Ulysses/ SSBUV-2	■ GRO	■ IML-1 ▲ Galileo at Earth
1991				■ ATLAS-1	■ SSBUV-3	■ SL-J		■ UARS ● EUVE	■ TSS-1	▲ Galileo Gaspra Flyby		■ LAGEOS II
1992		▲ Ulysses Jupiter Flyby ■ USMP-1	■ USML-1	■ ACTS	■ SL-02	■ ATLAS-2 ● TOPEX/ POSEIDON ● SAMPEX	● Geostat		■ SLS-2 ● Mars Observer			● Wind
1993	■ IML-2		■ USMP-2	■ ATLAS-3/ SPAS/ CRISTA/ SSBUV-4		■ HST REV ● Polar ● TOMS ● SWAS		▲ Mars Observer Arrival at Mars ▲ Galileo Ida Flyby	■ SRL-1	● MSAT	■ USMP-3/ STORE	● FAST
1994			■ ATLAS-4/ SSBUV-5	■ USML-2		■ USMP-4/ STORE	■ XTE	▲ Ulysses Over Sun's South Pole	● Small Explorer-4	■ SSBUV-6		■ SRL-2 ● Lifesat-1
1995	■ OMV/WISP	■ SLS-3	● SOHO			▲ Ulysses Over Sun's North Pole ■ IML-3 ● Small Explorer-5 ● Lifesat-2		● CRAF	■ ATLAS-5/ SSBUV-7			▲ Galileo Arrives at Jupiter ● Small Explorer-6 ● Lifesat-3
1996	■ SSBUV-8			● Cassini	■ USML-3 ■ SRL-3	● Lifesat-4 ● Small Explorer-7	■ USMP-5	■ ATLAS-6/ SSBUV-8		● Lunar Observer		

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NASA

PRESIDENT BUSH AND THE SPACE EXPLORATION INITIATIVE

Speech - July 20, 1989	Commitment and Direction	Space Station, the Moon, then Mars
Speech - February 2, 1990	The Goal	To place American on Mars
Decision - February 21, 1990	Policy Guidance	Technology and mission architectures
Announcement - March 30, 1990	International Guidance	Exploratory dialogue with other nations
FY 1991 budget request to Congress	Budget Request	Funds to begin preliminary planning

NASA

THE PRESIDENT STATES THE GOAL

"Our goal: To place Americans on Mars—and to do it within the working lifetimes of scientists and engineers who will be recruited for the effort today. And just as Jefferson sent Lewis and Clark to open the continent, our commitment to the Moon/Mars initiative will open the Universe. It's the opportunity of a lifetime—and offers a lifetime of opportunity."

President George Bush
Remarks at the University of Tennessee
February 2, 1990

NASA

PRESIDENTIAL DECISION ON THE SPACE EXPLORATION INITIATIVE

On February 16, 1990 President Bush approved policy for the Space Exploration Initiative:

- Initiative will include both Lunar and Mars program elements, as well as robotic science missions
- Near-term focus will be on technology development
  - Search for new/innovative approaches and technology
  - Investment in high leverage innovative technologies with potential to make a major impact on cost, schedule, and/or performance
  - In parallel with mission, concept, and system analysis studies
- Selection of a baseline program architecture will occur after several years of defining two or more reference architectures while developing and demonstrating broad technologies
- NASA will be the principal implementing agency while DOD and DOE also will have major roles in technology development and concept definition. The National Space Council will coordinate the development of an implementation strategy by the three agencies

NASA

NATIONAL SPACE POLICY – GOALS

On November 2, 1989, the President approved a national space policy that updates and reaffirms U.S. goals and activities in space.

- Strengthen the security of the United States
- Obtain scientific, technological, and economic benefits
- Encourage private sector investment
- Promote international cooperative activities
- Maintain freedom of space for all activities
- Expand human presence and activity beyond Earth orbit into the solar system

NASA

WHY GO TO THE MOON FIRST?

Learn to build, live and work on planetary surface close to home

Nearby — a 3-day trip and near instantaneous communications

Human experience in partial gravity leads to Mars

New science opportunities

Significant achievement by early next century

An evolutionary approach to "expanding human presence and activity"

NASA

EARTH-MOON-MARS PARAMETERS

The Moon

- 239,000 miles from Earth to Moon
- 1/4 diameter of Earth
- 1/6 Earth's gravity
- Lunar day is 28 Earth days
- Trip time: 3 days one way
- *Launch opportunity every month*
- *Communication time: 2.6 seconds roundtrip*

Mars

- 141.6 million miles from Sun
  - Earth is 93 million miles
- 1/2 diameter of Earth
- 1/3 Earth's gravity
- Martian day is 24 hours 37 minutes
  - Martian year is 1.88 Earth years
- Trip time: 6 months to 1 year one way
- *Launch opportunity every 26 months*
- *Communication time: 10.2-41 minutes roundtrip*

NASA

NASA'S 90-DAY STUDY

In response to the President's speech, the NASA Administrator created a task force, headed by Aaron Cohen, director of the Johnson Space Center, to conduct a study of the main elements of an Exploration Initiative

The study provides reference material in support of the Vice President and the National Space Council, and enables NASA to better understand technical parameters

The study examined

- technical scenarios
- science opportunities
- required technologies
- international considerations
- institutional strengths and needs
- resource estimates

NASA's study consists of analysis, not recommendations. It summarizes extensive trade studies, reflecting several years of study. It is not a definitive program plan

NASA

EXPLORATION APPROACH

Build upon past and present investments in space

- Apollo, Viking, etc.
- Space Shuttle
- Space Station Freedom

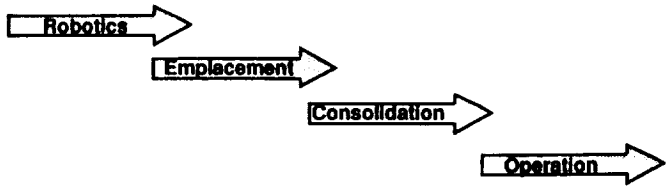
Employ robotic craft along with manned systems

Emphasize science

Build a lunar outpost first

- Research base for science and technology
- Test-bed for humans to Mars

Explore Moon and Mars in phases



NASA

NASA 90-DAY STUDY

Major Questions

- Scale
- Schedule
- Emphasis
- Technology
- Cost

DATABASE DEVELOPMENT

Reference Approach A	Reference Approach B	Reference Approach C	Reference Approach D	Reference Approach E
• Larger scale • Early lunar activity • Emphasize lunar science	• Larger scale • Early Mars activity • Emphasize Moon as Mars test-bed • Reduce Mars technology level	• Larger scale • Early lunar self-sufficiency • Reduced lunar logistics	• Larger scale • Later lunar activity • Later Mars activity • Increased technology	• Reduced scale • Later lunar activity

Report to Administrator

Database:
- Mission Definition
- Technical Description
- Costs and resources
- Technology

Assessments:
- Science
- Supporting programs
- Benefits
- Management
- International

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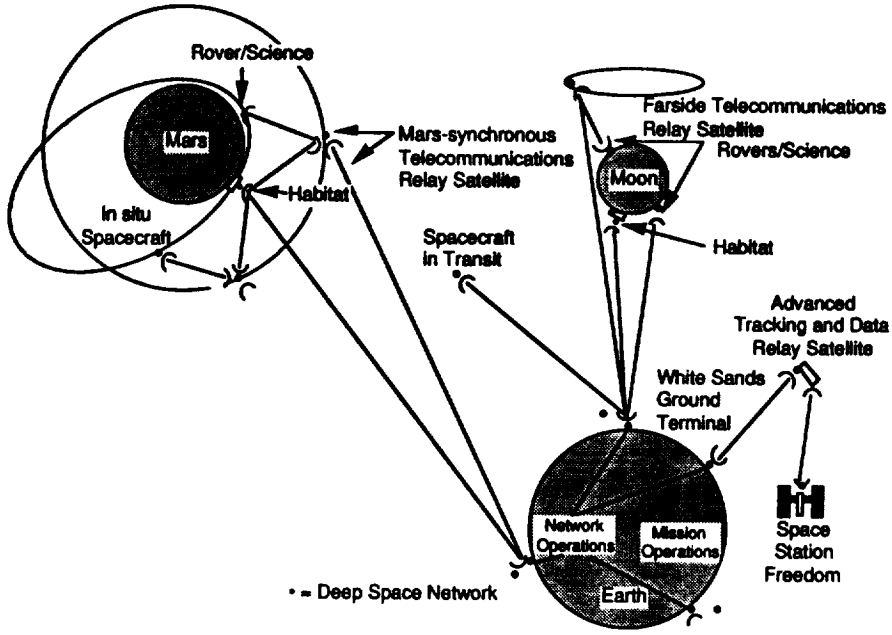
TELECOMMUNICATIONS ARCHITECTURE FOR THE HUMAN EXPLORATION INITIATIVE



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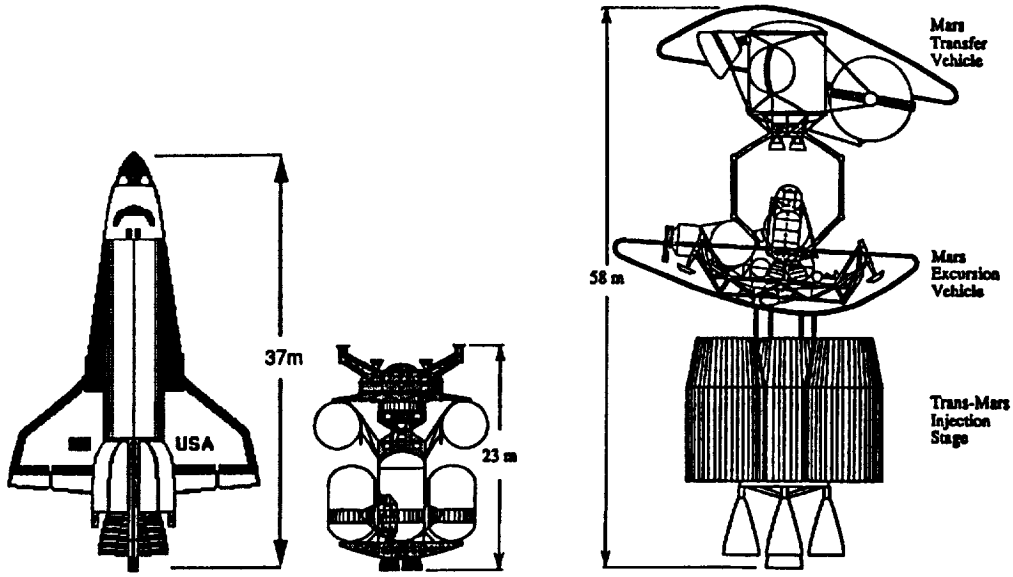
SHUTTLE AND LUNAR/MARS TRANSFER VEHICLES



Space Shuttle
Mass = 92 metric tons
(Payload = 22 metric tons)

Lunar Transportation System
Mass = 200 metric tons

Mars Transportation System
Mass = 800 metric tons

NASA

CONCLUSIONS OF THE 90-DAY STUDY

- Major investments in challenging technologies are required
- Scientific opportunities are considerable
- Robotic spacecraft will be needed
- Current launch capabilities are inadequate
- Space Station Freedom is essential
- Program alternatives do exist
- Opportunities for international cooperation exist
- A long-range commitment and significant resources will be required

NASA

THE NRC REPORT

- At the request of the Vice President, the National Research Council (NRC) reviewed NASA's 90-Day Report
- NRC's February 1990 report *(Human Exploration of Space)* examined
  - mission concepts
  - technology development
  - humans in space
  - science goals
- The NRC concluded that NASA's mission concepts "prudently build on proven concepts and methodical research, development, and demonstration of new technology. The concepts are comprehensive and robust, implying relatively low risk."
- The NRC also concluded that NASA has the organizational expertise and demonstrated capability to conduct human space exploration, and that other organizations should be utilized as well

NASA

NRC REPORT: SELECTED OBSERVATIONS

- The eventual choice of mission architecture likely will incorporate the ideas from a variety of mission concepts
- Research on the effects of microgravity upon human performance and welfare during long duration spaceflight is essential
- Space Station Freedom is an integral first step, but its present design may not meet all Exploration Initiative requirements
- A new generation of heavy-lift launch vehicles is needed
- Nuclear power eventually will be essential for lunar and Mars bases
- A balanced technology development program with emphasis on critical long-term technologies can help reduce risks and provide important options for the future
- While science is an integral part of NASA's plans, much of the research in NASA's scientific themes does not require an Exploration Initiative

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PREREQUISITES FOR HUMAN EXPLORATION

- Exploration technology
- Life sciences research
- Heavy-lift launch and orbital transfer vehicles
- Robotic missions
- Space Station Freedom

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EXPLORATION TECHNOLOGY PROGRAM

Space Transportation
- **Aerobraking; Space Based Engines;** and Autonomous Vehicle Maneuvering

In-Space Operations
- Cryogenic Fluid Systems; In-Space Assembly and Construction; and Vehicle Servicing and Processing

Surface Operations
- **Space Nuclear Power; In Situ Resource Utilization;** Planetary Rovers; Surface Solar Power; and Surface Habitats and Construction

Human Support
- **Regenerative Life Support; Radiation Protection;** Extravehicular Activity Systems; and Exploration Human Factors

Lunar and Mars Science
- Sample Acquisition, Analysis and Preservation; and Planetary Probes and Penetrators

Information Systems and Automation
- High-Rate Communications; Exploration Automation and Robotics; and Planetary Photonics

Nuclear Propulsion
- **Nuclear Thermal Propulsion;** and **Nuclear Electric Propulsion**

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TECHNOLOGY REPORT TO CONGRESS

Concerns: NASA's space technology programs not sufficiently focused to meet the needs of long-term space exploration as outlined in the President's speech in July 1989.

Requirement: *Provide a report by February 1, 1990** on specific technologies needed to meet the development and operational requirements of the President's space exploration initiative.

- Prioritize technologies both technically and financially
- Include five-year funding profile

Source: Senate Appropriations Committee Report accompanying H.R. 2916, the Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriation Bill, 1990, page 113.

In preparation

NASA

EXPLORATION LIFE SCIENCES

- Radiation Protection
- Reduced Gravity Countermeasures
- Life Support in Habitats and Space Vehicles
- Extravehicular Activity
- Medical Care
- Behavior and Performance

Earth ➡ Freedom ➡ Lunar Outpost ➡ Mars

NASA

RADIATION PROTECTION

Earth's magnetic field protects us from radiation emitted by solar flares, and shields us from galactic cosmic rays

Radiation beyond Earth orbit is cause for concern

Radiation strategy for the Exploration Initiative includes

- determination of career dose limits and crew selection criteria
- development of countermeasures
- development of shielding strategy for both vehicles and habitats
- development of early warning systems and "storm shelters" for protection from solar flare radiation

NASA will develop guidelines with the National Council on Radiation Protection and Measurements

- NASA will adhere to the radiation principle of as low as reasonably achievable (ALARA)

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ARTIFICIAL GRAVITY?

Microgravity exposure causes major physiological change

- Bone mineral loss
- Muscle atrophy
- Cardiac deconditioning

Current countermeasures (exercise) may be insufficient for the lengthy voyage to Mars

Strategy to test and evaluate necessary zero-g countermeasures will utilize

- Soviet long duration experience
- Space Shuttle extended duration orbiter
- Space Station Freedom and eventually
- The lunar outpost itself

Current approach: plan a zero-g Mars transfer vehicle, but begin low level definition of an artificial gravity system just in case

Humans must be certified for journey to Mars

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HEAVY LIFT LAUNCH VEHICLE

Exploration Initiative requires enhancement of current launch vehicle capabilities

Earth-to-orbit lift capabilities are estimated to be:

- Moon: 60 - 70 metric tons
- Mars: 140 metric tons

New launch vehicle development candidates include:

- Shuttle-C
- Advanced Launch System

There are no major technical impediments to building the heavy-lift launch vehicles we need

Expendable vehicles to play key role in Exploration Initiative

We ought to be initiating development

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ROBOTIC SPACECRAFT

Key tasks

- Determine suitable/desirable landing and outpost sites
- Provide design data for human mission elements
- Conduct science investigations and develop basis for human science exploration
- Demonstrate technologies and operation concepts for human missions

For the Moon, emphasis on selecting landing/outpost site

- Lunar Observer

For Mars, emphasis on science and human mission success

- Mars Observer
- Global Network Mission
- Sample Return/Local Rover
- Site Reconnaissance Orbiter
- Mars Rovers

Robotic missions are integral to the Space Exploration Initiative

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SCIENCE: SIGNIFICANT OPPORTUNITIES

Excellent science to be done on both Moon and Mars

- Robotic science
- Human interactive science

Fundamental scientific themes

- Origin and history of Earth and Moon
- The origin of life/life on Mars
- Global climate change
- Search for other solar systems
- Fate of the Universe

Research opportunities cover many disciplines

- Solar Physics
- Geology
- Biology
- Astrophysics
- Chemistry
- Space Physics

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SCIENCE ON THE MOON

Lunar origin/evolution

- Impact origin theory ⇨ common origin with Earth
- Larger role for planetary scale collisions?

History of the Sun (preserved in lunar soil)

- Solar wind trapped in regolith
- Buried regolith provides time resolution

Extinctions caused by impacts

- Evidence in lunar cratering record?

Unparalleled resolution, sensitivity for astronomy/astrophysics

- Large apertures
- Interferometric arrays
- Cosmic Ray Observatory

Life science

- Basic research: radiation environment, low gravity effects ...
- Supporting Mars exploration

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SCIENCE ON MARS

Planet most like Earth

- Has an atmosphere, evidence of warmer past
- Mars has intrigued humans for generations

Search for life on Mars

- Life may have existed long ago
- It may still exist in protected underground environments
- Answers will provide clues about evolution of life

Global climate change on Mars

- Examine chronology, characteristics of changes
- Understand role of geologic processes (e.g., volcanism, weathering)
- May enhance our understanding of changes on Earth

Human and robotic exploration

- Both important for complex field studies

Human presence key to advancing understanding

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INTERNATIONAL COOPERATION

Precedents are mixed

- Apollo/Viking: U.S. only
- Space Shuttle: primarily U.S.
- Space Station Freedom: international partnership
- Hubble Space Telescope: international participation

Advantages are significant

- Access to first-rate technical capabilities
- Reduction in costs
- Stronger ties with other nations
- Foreign resources tied to U.S. initiative

Disadvantages not to be discounted

- Dilution of control
- Management complexity
- Reduced U.S. leadership
- Vulnerable to political climate

Significant opportunities exist

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AN EXPLORATORY DIALOGUE

On March 30, 1990 the White House announced that the United States would seek an exploratory dialogue with other nations on international cooperation in the Space Exploration Initiative. Specifically, the President decided that:

- "The United States will take a sequential and orderly approach to decisions on involving specific countries consistent with decisions made on the overall Space Exploration Initiative.
- The United States will seek an exploratory dialogue with Europe, Canada, Japan, the Soviet Union, and other nations as appropriate on international cooperation on the Initiative.
- The exploratory dialogue will focus solely on conceptual possibilities for cooperation.
- The dialogue will be based on guidelines expeditiously prepared by the National Space Council. The guidelines will be consistent with the National Space Policy, taking due account of U.S. national security, foreign policy, scientific, and economic interests.
- The National Space Council will ensure interagency coordination and review during the development of international cooperation on the Initiative, and provide recommendations to the President as appropriate."

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"AN INTERNATIONAL FLAVOUR"

"I think we can afford to go it alone to achieve our goals, but I think that probably in the long run that is not what is going to happen. The world has changed since the 1960s. It used to be only the Soviet Union and the United States that could fly in space: that's the way it was when President Kennedy made his speech. The world has changed. The Europeans, the Japanese, the Canadians, the Chinese — all of these countries in this brief 20 years now have the capability to fly in space. Space Station Freedom is an international project. It is premature to know where we are heading so far as mission to the Moon and Mars are concerned, but I would think they will have an international flavour."

Richard H. Truly
Space Technology International 1990
Page 36

NASA

CURRENT ACTIVITIES

- Considering a nation-wide outreach program to search for additional Exploration Initiative ideas and technologies
- Continuing our preliminary science planning in conjunction with the Office of Space Science and Applications
- Developing implementation plans for exploration technology initiatives
- Planning exploration mission studies
- Working with National Space Council staff to develop guidelines for an exploratory dialogue with other countries
- Seeking support for the FY 1991 budget request

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MISSION ARCHITECTURE

- "Mission architecture" is the complete, integrated set of elements and systems necessary to carry out a mission
- Mission architecture shapes, and is shaped by, the overall mission objectives and strategy
- A major thrust of NASA's current Space Exploration Initiative activity is identifying and studying mission architecture options
- Technology development and mission architecture definition must proceed together
- NASA expects other agencies will participate in the SEI mission architecture analysis
- The key goal is to define two or more significantly different reference mission architectures

NASA

EXTERNAL REVIEWS

- National Space Council
- NASA Advisory Council
  - Exploration Task Force
  - Space Systems and Technology Advisory Committee
- National Research Council
  - Space Studies Board
  - Committee on Human Exploration
  - Aeronautics and Space Engineering Board
- Exploration Science Working Group
- Aerospace Industries Association

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OTHER AGENCIES

- The Space Exploration Initiative is a national endeavor, not a NASA project
- Agencies in addition to NASA, most likely the Department of Energy (DOE) and the Department of Defense (DOD) have expertise needed for the Initiative
- Recent Presidential decision mandates DOE and DOD role in technology development and concept definition
- NASA welcomes participation by other agencies in the Space Exploration Initiative

PAYLOADS AND PEOPLE TO ORBIT

To realize the vast potential of space and to achieve the benefit from space in science, technology and commerce, you must first get there. Transportation, as always, is critical. Payloads must be placed in orbit. The Space Shuttle is important because it carries these payloads into space. The Shuttle is a heavy lift launch vehicle. The United States relies on the Shuttle to transport a variety of spacecraft to where they need to go. If the destination is low Earth orbit, the Space Shuttle brings them up. If the objective is geosynchronous orbit or another planet, the Shuttle brings the payload to about 250 miles above the Earth from where it is propelled to its destination. Despite its technical complexity and sophistication, the Space Shuttle is conceptually simple. It is a truck to transport things into space. During the first period of Shuttle operations, from 1981-1986, it hauled a vast amount of cargo. Four orbiters, in 24 flights, carried numerous payloads aloft, as shown on page 6. The future looks equally busy. The Space Shuttle's manifest continues to be booked out to the horizon of our planning. I have no doubt the Shuttle will be flying throughout the first decade of the twenty-first century, lifting payloads into orbit and demonstrating its value as a national space launch vehicle.

But the Space Shuttle is much more than simply a launch vehicle. What makes it unique, what marks it as a resource of extraordinary value to the United States, is that it carries more than heavy cargo. It transports men and women into space. It enables them to live and work on orbit and then returns them safely to Earth. Moreover, the Shuttle is reusable—the first such craft in the world. The Space Shuttle works in four distinct regimes: it is a launch vehicle bringing people and payloads to and from space. As a versatile spacecraft circling the Earth, it provides time on orbit for human beings. It is a reentry vehicle gliding safely through the atmosphere at such high speed that the molecules of air have difficulty getting out of the way. And then, at the end of its flight profile, the Shuttle is an aerodynamic vehicle—a glider that is flown to land upon a runway.

The fundamental purpose of the Space Shuttle is to place human beings into space, then return them safely and lift them aloft once again.

ORBITER	DATE	PAYLOAD
1. Columbia	April 12, 1981	Flight Instrumentation
2. Columbia	November 12, 1981	OSTA-1, First RMS, Flight Instrumentation
3. Columbia	March 22, 1982	OSS-1, Flight Instrumentation
4. Columbia	June 27, 1982	DOD, Flight Instrumentation
5. Columbia	November 11, 1982	SBS-C, Telesat E
6. Challenger	April 4, 1983	TDRS A
7. Challenger	June 18, 1983	SPAS-01, OSTA-2, Telesat F, Palapa B-1
8. Challenger	August 30, 1983	PDRS/PFTA, OIM, INSAT 1-B
9. Columbia	November 28, 1983	Spacelab 1
10. Challenger	February 3, 1984	SPAS-01A, Palapa B-2, Westar 6
11. Challenger	April 6, 1984	LDEF, SMM Repair
12. Discovery	August 30, 1984	OAST-1, SBS-D, Telestar 3-C, Syncom IV-2
13. Challenger	October 5, 1984	OSTA-3, ERBS, LFC/ORS
14. Discovery	November 8, 1984	HS-376 RETV(2), Telesat H, Syncom IV-1
15. Discovery	January 24, 1985	DOD
16. Discovery	April 12, 1985	Telesat I, Syncom IV-3
17. Challenger	April 29, 1985	Spacelab 3
18. Discovery	June 17, 1985	Spartan, Morelos A, Arabsat 1-B, Telestar 3-D
19. Challenger	July 29, 1985	Spacelab 2
20. Discovery	August 27, 1985	Aussat 1, ASC-1, Syncom IV-4
21. Altantis	October 3, 1985	DOD
22. Challenger	October 30, 1985	Spacelab D-1
23. Atlantis	November 26, 1985	EASE/ACCESS, Morelos B, Satcom KU-2, Aussat 2
24. Columbia	January 12, 1986	MSL-2, Satcom KU-1, Gas Bridge
25. Challenger	January 28, 1986	TDRS B

The Space Shuttle is important because space transportation and manned space flight are now essential to the well being of the United States.

Space has become a place where extremely useful and worthwhile activities occur, and space transportation is always the first step. Some of these activities can be done only in space. Some can be done better in space than on Earth. No longer limited to high adventure and occasional spectaculars, space provides practical benefits we now take for granted. It also provides opportunities for science, commerce, and international cooperation.

The practical benefits are many. Communications, navigation, and weather prediction are all now space dependent. Remote sensing spacecraft aid a host of other activities including agriculture, petroleum exploration, map making, environmental protection, and urban planning. In truth, our society has come to rely upon the now everyday capability of modern space systems.

Science also benefits from space. Space provides such a rich environment for the advancement of knowledge that science and technology now have a core dimension rooted in space. Research in space is remarkably diverse. It examines near-term concerns such as ozone depletion that may affect the atmosphere's ability to shield us from harmful radiation. It seeks ultrapure pharmaceuticals, uniform semiconductor crystals, and new glasses and alloys from the microgravity environment of space. With a longer focus, it looks at the Sun and the planets to learn more about life and the one planet in the solar system that supports it. And, with incredibly sophisticated orbiting observatories, space research peers across the electromagnetic spectrum into distant galaxies in search of answers to fundamental questions about human and physical existence.

Yet space is more than a laboratory for science or a source of practical applications. It is also a place of business. Private companies conduct extensive activities focusing upon space. Some build space hardware; some sell support equipment and services. Some simply utilize the capabilities provided by spacecraft. Newspapers, for example, rely upon space systems for printing. Space is a place of profit and of competition.

This competition is not simply commercial in character. In the decade of the 1980's, the space programs of Europe have matured and challenge our own. Japan and China are becoming major spacefaring nations. The Soviet Union is accelerating its already impressive space program. These countries understand that profit, productivity, prestige, and power are the products of investments in space. U.S. leadership among spacefaring nations has eroded. The implications of this affect not only our science, technology, and commerce, but also our national security. As importantly, it affects the confidence with which Americans face the future.

While competition in space flourishes, so does international cooperation. At the same time that we compete, we conduct cooperative activities. Through NASA, the United States has engaged in a large number of highly successful space missions with allies and friends. These missions are usually scientific in character. While they support our foreign policy objectives, they more directly add to our storehouse of knowledge. And they demonstrate the peaceful use of space for the benefit of all.

We risk great peril if we kill off the spirit of adventure, for we cannot predict how and in what seemingly unrelated fields it will manifest itself. A nation which loses its forward thrust is in danger, and one of the most effective ways to retain that thrust is to keep exploring possibilities. The sense of exploration is intimately bound up with human resolve, and for a nation to believe that it is still committed to forward motion is to ensure its continuance.

James A. Michener
February 1, 1979

MEN AND WOMEN IN SPACE

The rationale for having men and women in space rests upon utility as much as anything else. While there is an emotional, intangible dimension to the human presence in space, there is, decidedly, a compelling practical value as well.

The presence of astronauts significantly enhances the utility of spacecraft. The output, the results and the benefits derived are far greater when humans are present. After all, human beings are the most sophisticated machines of all. Their creativity, their dexterity, their ability to perceive, their interaction with instruments and each other, and their ability to respond to the unexpected are unmatched. Whether piloting the Shuttle, controlling its Remote Manipulator System (the Shuttle's Canadian developed high-tech crane), or conducting scientific experiments in Spacelab (the European laboratory module that sits in the payload bay), the presence of a crew brings unique and extraordinary capabilities to space. Humans can fix things. They can redirect or reprogram their activities. As Neil Armstrong showed during the Apollo 11 descent to the lunar surface, they can steer clear of unexpected obstacles. They also can do what machines simply cannot. They can act upon hunches and they can channel intuition. Although requiring extensive life support systems, humans in space bring expertise and imagination to the cockpit and to the laboratory. Their presence increases immeasurably our orbital capabilities.

Space science traditionally has been best served by a balance of manned and unmanned missions. The crew's influence on the three Spacelab flights and in the conduct of numerous middeck experiments has demonstrated great benefits. Having scientists in the laboratory is hardly revolutionary. We do it all the time on Earth. On Earth the scientist prepares the experiment, monitors its progress, and shuts it down when necessary. The scientist in space interacts with the experiment in the same way. He or she reads the data and makes realtime adjustments. The scientist is there to interpret, to react, to fix, and to do it again. When we have the capability to place scientists in an orbiting laboratory, as we do now with Shuttle and will be able to do so more extensively in the future with the Space Station, we do so. When simply not possible, as in a mission to the outer planets, we do not. We then rely upon sophisticated unmanned spacecraft. Each approach is valid. Each brings rewards. In a balanced approach to space exploration, NASA conducts both unmanned research and manned space flight. Each has its place. And neither is independent of the other. The unmanned scientific expedition requires the guiding hand of the flight director and the flexible mind of the principal investigator (they just happen not to be onboard). And when the astronauts are conducting experiments in Spacelab or on the middeck, they are completely dependent upon automated systems that sense, calculate, and switch at speeds and reliability no human can match. Manned space flight requires the technology of unmanned systems. Unmanned scientific spacecraft require the presence of men and women. A balanced U.S. space program needs and will continue to need both.

HUMAN EXPLORATION

Along with the utility of having humans in space lies the emotional value and intellectual dimension of human exploration. To deny these ignores a fundamental dimension of life.

Consider first the emotional value of space flight. People are human. They react with their heart as well as their mind. The excitement of space flight has thrilled people well before Uri Gagarin and the Mercury astronauts pioneered manned flight around the Earth. The adventure of space exploration by men and women, the purview no longer of fiction but of engineering, continues to fascinate people here in the United States and around the globe. No one who has witnessed the launch of a Saturn V rocket with Apollo astronauts on board or seen the Space Shuttle lift off from Cape Canaveral can fail to experience the excitement. An adventure has begun. Despite the display of technology, the adventure is intensely personal. Being there, seeing it and hearing it, compels you to wish the astronauts God Speed as they are hurtled into space. A Shuttle launch leads to a binding, an awareness of a common trait shared with the crew and with the people who are there. We are all human beings. Our lives are intertwined. Our future is one. Their success is our success. In times of triumph and, as we learned with the loss of Challenger, in times of tragedy, space exploration expresses a profound sense of brotherhood.

The intellectual character of manned space flight is no less real than its emotional dimension. We place men and women into orbit in order to learn. Learning is not the only reason, but it is an important reason. Exploration is a human imperative laced with a sense of adventure, buttressed by a need to know. Being there in person enables us to know more. Astronauts (and cosmonauts) can see and measure and look further still. They question and think and question again. Until we are physically there, we will not fully understand. This need to know has driven human exploration throughout the ages. It drove Vasco de Gama to the Cape of Good Hope. It sent seaman such as Cabot and Frosbisher to Canadian waters in quest of a Northwest Passage. It sent Lewis and Clark up the Mississippi River. It drove the great navigators Cook and deBougainville to the Southwest Pacific. Of course, it was not just a pure desire to explore that propelled these astronauts of their day. Nationalism, the scent of profit and what Daniel Boone called "Elbow Room," contributed, but the necessity of learning played a key part. Men and women are more than economic creatures and patriots. They are seekers of knowledge, inquisitive types, who are borne with a desire to learn. Curiosity motivates human behavior. The exploration of space by men and women reflects this. It adds to our understanding. It stimulates our minds. It enables us to question further and to delve deeper.

NATIONAL SPACE POLICY

Human exploration of space is not just a mission of NASA or simply the dreams of a few visionaries. It is an objective of the United States government and is reflected in our national space policy. Adopted in early 1988, this space policy sets forth a set of goals and objectives to direct U.S. efforts in space for the future. The policy, manifested through a Presidential directive, reaffirms the national commitment to the exploration and use of space. It sets, as a long-term goal, human expansion beyond Earth orbit. It acknowledges that U.S. space activities are conducted by three separate and distinct (though interactive) sectors: civil, national security, and commercial. Most importantly, the directive states that a fundamental objective guiding U.S. activities in space has been, and continues to be, leadership in space.

The policy directs NASA to conduct a balanced program of manned and unmanned space exploration. Preeminence in critical aspects of manned space flight is mandated. The policy sees efforts to improve Space Shuttle performance and to develop the Space Station as intended to ensure such preeminence. Indeed, I believe these efforts are vital. A robust Shuttle fleet and a permanently manned Station are essential to the United States. Without them, the 1990's and the first decade of the twenty-first century would be a time when our abdication of space leadership becomes evident.

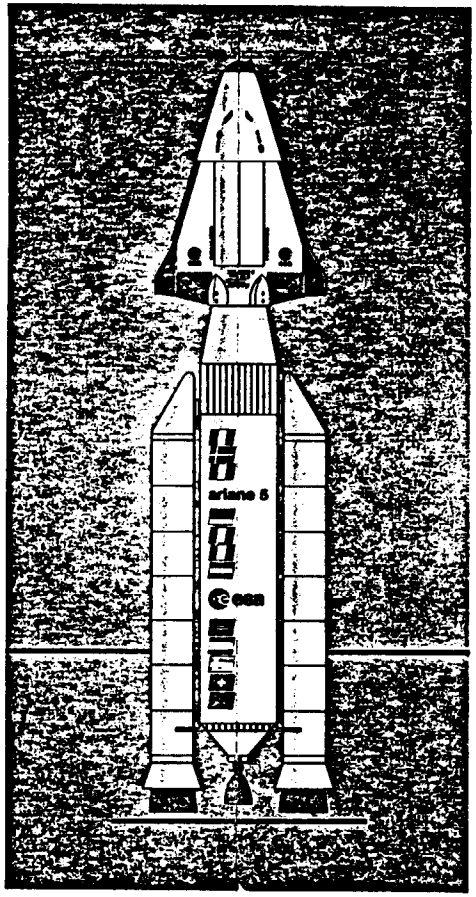
Our national space policy speaks directly to the subject of space transportation. It recognizes the link between transportation and the benefits of space. The policy calls for assured access to space and for transportation capabilities in space. It states the U.S. space transportation systems must provide a balanced, robust and flexible capability. The system must be sufficiently resilient to allow continued operations despite failures in any single system. The policy further states that we will exploit the unique attributes of both manned and unmanned launch systems. It encourages the development of private sector space transportation systems. It sets as a goal the reduction of space transportation costs.

COMPETITION IN SPACE FLIGHT

The Space Shuttle is a unique space launch system. It is "man-rated" and reusable and has carried a vast amount of cargo into space. It also has carried cargo back from space. The Soviet Union will soon be flying a Shuttle-like reusable craft to carry cosmonauts and cargo into space and back. In the 1990's, the Soviet Shuttle no doubt will be a regular caller at MIR, the Soviet space station. Mated to the Energia launch vehicle, the world's largest rocket, the Soviet Shuttle will comprise an impressive capability. The Soviet record in space is already impressive. At the end of 1987, of the 1,736 payloads in orbit, more than half (1,045) belong to the Soviet Union. The Soviets are totally committed to space. They recognize fully its many benefits.

However, the two superpowers are not the only countries in the business of manned space flight. The countries of Europe, organized as the European Space Agency (ESA), have built the Spacelab and have established a small corps of astronauts. Some of these astronauts have flown in the Shuttle. Spacelab is a highly capable laboratory in space whose development enabled the Europeans to gain manned space flight experience at bargain prices. Europe's stated goal in space is autonomous manned capabilities. To achieve this, ESA has begun development planning for the Ariane V launch vehicle and the Hermes manned space plane. The former is an advanced technology heavy lift expendable launch vehicle. The latter is a small reusable space plane whose first manned flight is targeted for 1999. An illustration of the Hermes craft atop an Ariane V is shown on page 14.

Competition among nations in expendable launch vehicles is substantial. While manned space flight at present is dominated by the United States and the Soviet Union, a number of countries build and market unmanned expendable vehicles. One of the most successful vehicles is Ariane. Built by the Europeans, and marketed commercially by a private company, Ariane has placed in orbit both communications satellites and scientific spacecraft. Launched from the ESA facilities in Kourou, Guiana, Ariane has flown 23 times since 1979. Nineteen of these flights have been successful, four have failed. China too is now in the expendable launch vehicle business. Its Long March vehicle has flown successfully and is offered for sale on the world market. Japan is also building launch



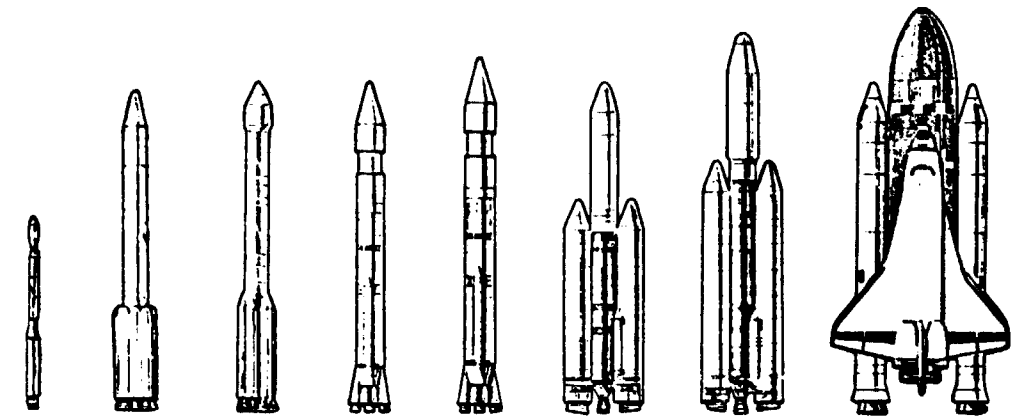
Both the Ariane V launch vehicle and the Hermes manned space plane (both illustrated here) are under development in Europe.

vehicles. Its H-I rocket based on U.S technology, has carried Japanese scientific spacecraft into orbit. Now in development is the H-II. This three-stage heavy lift vehicle will have an advanced liquid hydrogen-oxygen engine. Developed solely by the Japanese, the H-II is scheduled to become operational in the early 1990's. No doubt, it will make its presence felt. The Soviet Union also flies unmanned vehicles. The Proton rocket is the workhorse of the Soviet rocket fleet and recently has been offered commercially. Difficulties with utilizing Proton exist, but the Soviets are making a concerted effort to market the vehicle.

International competition in expendable launch vehicles is stiff. Europe, China, Japan, and the Soviet Union are flying vehicles now that compete with U.S. expendable launch vehicles. Moreover, they are developing more advanced rockets that will compete in the future. The extent of the competition reflects the maturity and availability of rocket technology. It also reflects the heavy demand for launch services which itself demonstrates the commercial and scientific value of space.

U.S. expendable launch vehicles, however, constitute an impressive capability. Given a level playing field, they can more than hold their own. With demand fostered by NASA and the Department of Defense, U.S. industry has supplied a variety of reliable vehicles to meet a diverse set of requirements. The Scout vehicle, built by the LTV Corporation, lifts small payloads into orbit. The Delta launch vehicle, manufactured by McDonnell Douglas, carries medium-sized payloads aloft and is a mainstay of the fleet. The Atlas vehicle, built by General Dynamics, lifts larger, intermediate payloads into orbit while Martin Marietta's Titan launch vehicle places heavy payloads into their orbital positions. These expendable launch vehicles are illustrated here as are foreign vehicles.

U.S. Launch Vehicles

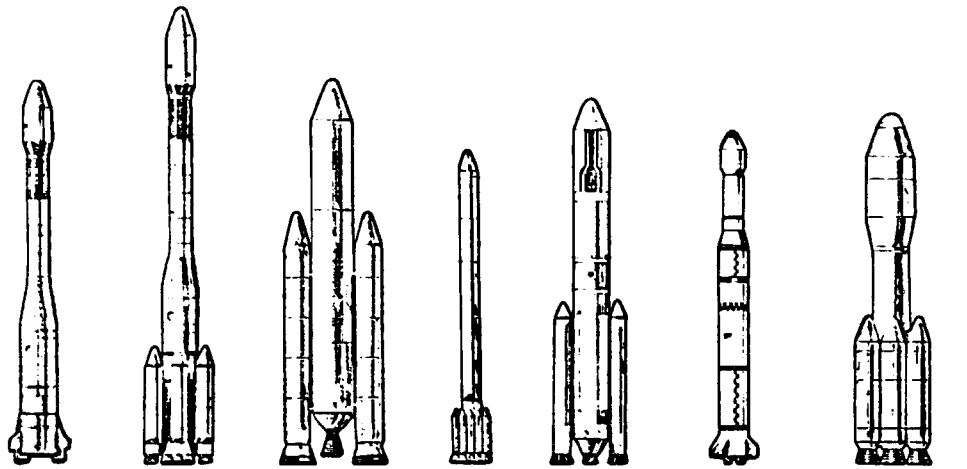


Scout	Delta	Delta 2	Atlas 1	Atlas 2	Titan 3	Titan 4	Shuttle
475 lbs.	7,800 lbs.	11,100 lbs.	12,300 lbs.	14,400 lbs.	33,000 lbs.	40,000 lbs.	55,000 lbs.

Pounds to Low Earth Orbit

The national space policy directs NASA to procure expendable launch services from the commercial space sector. The commercial launch services industry is now a reality. The U.S. space policy is intended to enhance the competitive posture of the American expendable launch vehicle industry.

Launch Vehicles of Europe, Japan and China

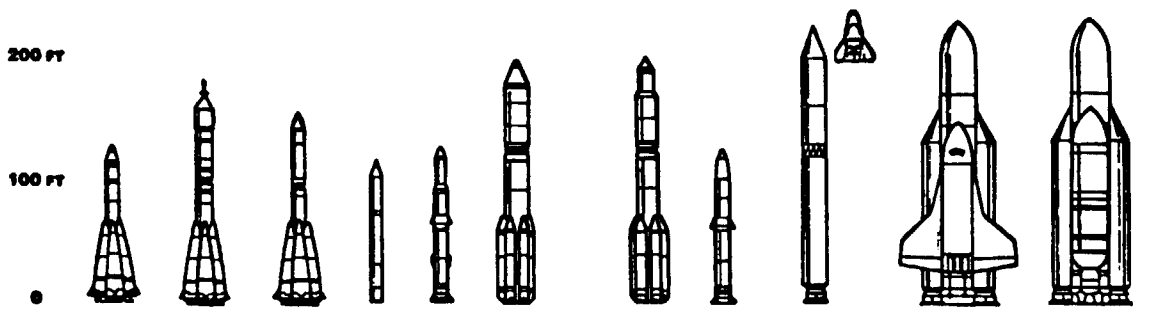


Ariane 3 (Europe) 5,690 lbs.	Ariane 4 (Europe) 9,260 lbs.	Ariane 5 (Europe) 14,960 lbs.	H-1 (Japan) 2,300 lbs.	H-2 (Japan) 9,000 lbs.	Long March 3 (China) 5,500 lbs.	Long March 4 (China) 8,800 lbs.

Pounds to Geosynchronous Transfer Orbit

Soviet Launch Vehicles

Energia Heavy Lift Vehicle



SL-3 13,900 lbs.	SL-4 16,500 lbs.	SL-6 4,600 lbs.	SL-8 3,800 lbs.	SL-11 8,800 lbs.	SL-12 43,000 lbs.	SL-13 43,000 lbs.	SL-14 12,100 lbs.	SL-16 33,000 lbs.	Shuttle 66,000 lbs.	Cargo 220,000 lbs.

TOMORROW'S LAUNCH VEHICLES

The U.S. expendable launch vehicle industry is developing advanced versions of current expendable vehicles. Most noteworthy are the Titan 4, Atlas 2 and Delta 2 vehicles of Martin Marietta, General Dynamics, and McDonnell Douglas, respectively. They reflect not only new requirements but the inevitable tendency in aerospace to upgrade performance through steady improvement. These new vehicles will ensure a competitive expendable launch vehicle fleet in the early 1990's, although the competition is clearly intent upon reducing the United States' market share of the launch business.

Despite the relative strength of the U.S. expendable launch fleet, there is cause for concern. Space transportation is an expensive proposition, and the vehicles we now have or are designing cannot lift the heavy payloads we will have in the next century. Reducing the cost of access to orbit is essential. So is increasing the performance of the next generation of launch vehicles. What is required are new technologies and, in effect, an advanced launch system. We need new launch vehicles that carry more and cost less. High performance, simple systems, large payload volume and robust and resilient design margins are required. Manufacturing and operational characteristics that emphasize automation, simplicity and reliability are also required.

NASA and the Air Force have a joint program to develop such an advanced launch system. It focuses upon technology and an end-to-end manufacturing system necessary to sustain an efficient production capability. The joint program has gotten off to a strong start. The advanced launch system is a research activity which will lead to a development effort. I believe it will result in a new family of launch vehicles that will carry us into the twenty-first century. It is an essential national investment.

Utilizing Shuttle hardware and experience, NASA could develop an unmanned version of the Space Shuttle that substitutes a large cargo carrier for the manned orbiter. Shuttle-C, as this concept is termed, is an attractive option providing an interim heavy lift capability at reduced expense. Shuttle-C is currently being defined by NASA and U.S. industry. Companies involved include McDonnell Douglas Astronautics, Rockwell International, and Martin Marietta which provided this illustration.

One heavy lift launch vehicle we might develop would be based upon the Space Shuttle. Utilizing Shuttle hardware, and experience, NASA could develop an unmanned version that substitutes a large cargo carrier for the manned orbiter. Shuttle-C (C for Cargo), as this concept is termed, is an attractive option. It would provide an interim heavy lift capability without the expense of building an entirely new system. It would take advantage of Shuttle technology, hardware, and flight experience. The Shuttle-C concept is illustrated above. NASA has conducted preliminary analysis establishing the feasibility of Shuttle-C. It would be a sound investment.

SHUTTLE RECOVERY AND IMPROVEMENT

The time when the Space Shuttle did not fly was time well spent by NASA. When we look back at 1986-1988, we will see it as a time when NASA and the country took an unwanted, but necessary, breather in the space program. During this time, we took a hard look at ourselves and at what we hoped to accomplish in space. What we saw was solid. Some things needed changing and changes were made. It was a time of introspection, not without pain, but mostly it was a time when we recharted our course and rededicated ourselves to space exploration. The shock and grief of Challenger never affected our determination to rebuild and fly again.

Policy issues were reexamined and, from the debate, a new space policy emerged. Requirements for launch vehicles were analyzed, and the concept of a mixed fleet was adopted. From this concept will come expendable launch vehicles for today and an advanced launch system for tomorrow. The role of the Space Shuttle was looked at too. The result was a recommitment to manned space flight, declared not just by words but by the decision to build a replacement orbiter. The Shuttle fleet will be brought back up to four. In 1991, a new orbiter will join Columbia, Discovery, and Atlantis.

The Shuttle system itself was thoroughly reexamined. A Failure Mode Effects Analysis, Hazard Analysis, and Criticality Review were performed on virtually every aspect of the program, extending to both ground and flight operations. The certification process for each item of hardware was examined in detail. Attention was devoted to areas that directly influence flight safety and mission success. An audit panel appointed by the National Research Council (NRC) verified the adequacy of the review effort. The NASA committees in the Senate and the House of Representatives conducted oversight hearings to monitor the effort. The review resulted in many redesigns that improved the Space Shuttle system. The process was scrutinized at each step of design and testing by the NRC, which reported its findings to Congress and to the Administrator.

Solid Rocket Booster (SRB) field joints, case-to-nozzle joints, and nozzle assemblies were redesigned and verified in extensive testing which included five full-scale motor firings. The redesigned joints performed flawlessly—so well, in fact, that deliberate flaws had to be introduced into test articles to assess their redundant characteristics. The Space Shuttle Main Engines (SSME) underwent more testing since the Challenger accident than than they did prior to the first Shuttle flight. One engine underwent testing to the equivalent of 80 flights. The design limit is 10 flights. Improvements were made to valves, plumbing, and engine subsystems. New inspection techniques were developed to detect flaws in welds and structural integrity. Such scrutiny was not restricted to hardware.

Management issues received comparable attention. The launch decision making process was reviewed and improvements were made in training, definition of responsibilities, and communications. Safety issues received renewed emphasis, and an Associate Administrator for Safety, Reliability, Maintainability and Quality Assurance was established. The Space Shuttle office was extensively restructured. The "lead center" concept—under which particular field centers exercised control over certain programs—was abolished, and in its place a strong central authority was created at the Headquarters level. A safety reporting program was established, modeled after a system used by the Federal Aviation Agency.

Concurrent with the recovery program, NASA continued to look at ways to improve the Shuttle's overall performance. A good flying machine is one that lends itself to incremental improvements over time. The Shuttle is such a machine. Two such improvements are under way. One deals with reaching space, the other with time on orbit. The first change is to the booster rocket. A new Advanced Solid Rocket Motor (ASRM) will be built to replace the booster we are now using. Safer and more reliable, the ASRM also will enhance performance. ASRM is scheduled to fly in 1994. The second improvement is called the Extended Duration Orbiter (EDO). Not a new vehicle, but rather a kit to be carried in the Shuttle's payload bay, the EDO will enable the orbiter to remain in space for longer periods of time. Carrying the necessary consumables, it will extend the astronaut's stay from 8 days in space to approximately 16 days. More time on orbit will enable men and women to better utilize the Shuttle as a platform for science, commerce, and technology. While no substitute for a permanently manned presence in space, the EDO is an important, interim step.

A NEW SHUTTLE FOR THE NEW CENTURY

The Space Shuttle will fly into the next century. The first orbiter, Columbia, first flew in 1981. I have no doubt it will still be flying in the year 2005. As we build up to a steady flight rate of 12-14 Shuttle flights a year, these remarkable vehicles will be hauling payloads and people into and back from orbit. Complemented by expendable launch vehicles, they will remain the backbone of our space transportation system.

Yet it is not too soon to begin thinking about what vehicle will follow our present Space Shuttle. Though durable, Columbia, Discovery, Atlantis, and the replacement orbiter will not fly forever. A few years into the twenty-first century, we should be building the first of the new reusable, man-rated spacecraft.

The next century may seem far away. It's not. Moreover, concept definition and preliminary design of the new craft will take 3-4 years; technology development will require more. Actually building the vehicle will take 4-5 years, and test and checkout will add another year or two. Like any major space flight development effort, the program will need about 10 years. So it is appropriate for us now to start considering what the new Shuttle should be like. Once the development cycle of the Space Station is behind us, in the early 1990's, NASA will be in a position to initiate the effort.

It is imperative that by the year 2005 or 2010, the United States has the new Shuttle operational. In the new century, space will continue to be a place for the advancement of science, the conduct of business and the development of technology. The practical benefits of space will increase, as will our everyday dependency upon spacecraft. Human exploration will continue too. The imperative to explore will place men and women in space. If not Americans, then the Russians, the Europeans, or the Japanese will push the space frontiers of adventure and knowledge. The new Space Shuttle will ensure that the United States will continue to lead the way.

WE CAN BE WHAT WE WANT TO BE

The space program of the United States is extraordinary. Technologically superb, intellectually rewarding, rich in heritage, witness to tragedy yet filled with triumph, the space program is a reflection of our country at its best. It is a success story of which we all can all be proud.

Today, our space program is at a crossroads. The Challenger loss is behind us and the Space Shuttle is returning to flight.

So we must now decide what our future in space will be. 1988 and 1989, and perhaps a year or two beyond, will set the course of NASA and America's space program for the next two decades. We have the technology and the experience to be the best. We must decide if the twenty-first century will see the United States as the preeminent spacefaring nation or simply one of several nations in space. We have the capability to be what we want to be. We can lead as we have done in the past, or we can simply remain a principal player. The choice is ours.

Research Program and Budgets

The following sections summarize the FY 1991 activities and budgets of the U.S. Global Change Research Program in the seven interdisciplinary science elements, by agency, by scientific objective including data management, by Federal budget function, and by the balance between space- and ground-based components. Because of the complex nature of the Program, examples of important research, data collection, and modeling activities will be mentioned along with how they address the research priorities and related policy-relevant questions.

Budget Overview

Table 1 shows the U.S. Global Change Research Program budget proposal by science element, by agency, and by scientific objective. In FY 1990 funding for the U.S. Global Change Research Program is $659.3 million.* The President's FY 1991 budget proposes a funding level of $1,034 million, a $374.8 million (57 percent) increase over the FY 1990 level. Table 2 shows the budgets for programs that contribute to global change research and provide important support to the Program objectives but were initiated for reasons other than the focused Program goal.

* The FY 1990 Program as outlined in the President's FY 1990 Budget to Congress was $190.5 million (see *Our Changing Planet: A U.S. Strategy for Global Change Research*, January 1989). The FY 1990 Program was adjusted to $659.3 million over the past year reflecting subsequent FY 1990 Appropriations actions by the Congress and the reevaluation of "focused" and "contributing" programs. The bulk of this increase is due to the transfer of several NASA programs from the "contributing" category.

Budget by Science Element

This section summarizes the FY 1991 activities in the seven interdisciplinary science elements and data management. Figure 2 shows the FY 1990 enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by science element. At this time the U.S. Global Change Research Program focuses primarily on the three highest priority science elements: Climate and Hydrologic Systems, Biogeochemical Dynamics, and Ecological Systems and Dynamics. However, the Program maintains an appropriate level of effort in all seven science elements consistent with the policy needs, science priorities, and the current state of scientific program development.

Figure 2
U.S. Global Change Research Program Budget by Science Element

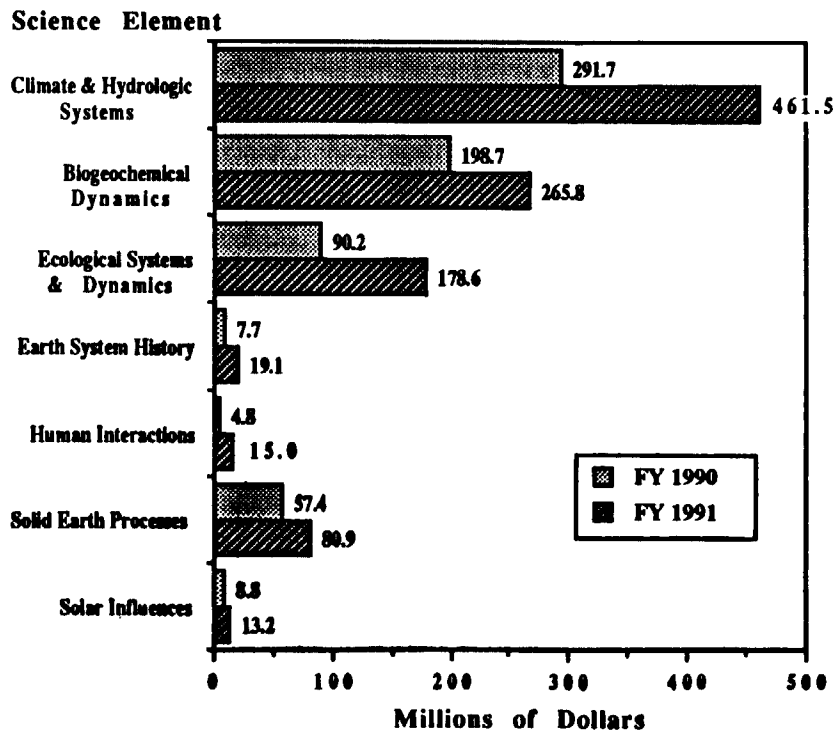


Table 1

FY 1990-1991 U. S. Global Change Research Program Focused Budget

(Dollars in Millions)

Focused Program	Total Budget		Climate & Hydrologic Systems		Biogeochemical Dynamics		Ecological and	Systems Dynamics	Earth System History		Human Interactions		Solid Earth Processes		Solar Influences	
	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91
Agency Totals	659.3	1034.1	291.7	461.5	198.7	265.8	90.2	178.6	7.7	19.1	4.8	15.0	57.4	80.9	8.8	13.2
DOC/NOAA	18.0	87.0	14.2	67.6	3.3	13.5	0.0	4.9	0.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0
DOE	50.0	66.0	32.0	44.0	7.0	9.0	9.0	10.0	0.0	0.0	2.0	3.0	0.0	0.0	0.0	0.0
DOI	13.3	43.7	4.9	12.2	0.8	2.0	0.9	10.3	2.4	8.0	0.9	5.3	3.4	5.9	0.0	0.0
EPA	13.2	26.0	1.0	3.3	2.5	3.1	9.7	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NASA	488.6	661.0	221.4	302.5	162.2	198.3	51.0	90.0	0.0	0.0	0.0	0.0	47.7	63.0	6.3	7.2
NSF	55.0	103.0	16.8	29.8	20.2	32.2	3.5	8.5	4.5	9.0	1.2	5.5	6.3	12.0	2.5	6.0
USDA	21.2	47.4	1.4	2.1	2.7	7.7	16.1	35.3	0.3	1.1	0.7	1.2	0.0	0.0	0.0	0.0
Scientific Objective																
Observations	137.2	255.0	89.1	148.9	17.2	38.9	14.1	39.6	0.0	0.2	0.0	2.2	13.1	20.8	3.7	4.4
Data Management	65.2	129.4	32.9	64.0	21.2	34.7	5.5	17.7	0.5	2.2	0.4	1.0	3.8	8.8	0.9	1.0
Understanding	409.7	560.0	143.1	200.3	148.1	176.2	65.5	103.2	6.1	13.1	2.9	10.6	40.5	50.1	3.5	6.5
Prediction	47.2	89.7	26.6	48.3	12.2	16.0	5.1	18.1	1.1	3.6	1.5	1.2	0.0	1.2	0.7	1.3

insight into potential sun–atmosphere couplings. NSF's Coupled Energetics and Dynamics of Atmospheric Regions (CEDAR) and Geospace Environment Modeling (GEM) programs will begin the establishment of data bases on solar inputs relevant to the global circulation and couplings.

(3) ***How does the sun's output vary and what is the impact on terrestrial climate?***

A key factor in establishing the Earth's radiation budget is the total solar radiation reaching the planet. This requires continuous measurements of the total solar radiation with very high long-term stability (0.1%). These observations will be provided by Active Cavity Radiometer Irradiance Monitors (ACRIM) on NASA's UARS and EOS.

Data Management

Table 1 shows that the FY 1991 request for data management is a $129.4 million, a $64.2 million or 98 percent increase over the FY 1990 level.

Data and information management will provide a bridge between global change observations and scientific understanding, and will be a key factor in the success of programs carried out within all seven interdisciplinary science elements. The traditional concepts and present practices of data management are inadequate for global change studies. The interdisciplinary, interagency, and international aspects of these studies, coupled with a long-term view, pose unprecedented challenges to the data management and research communities alike. Consequently, cooperation in seeking new approaches to archiving and management of data is essential.

Data management includes the means and mechanisms to describe, gather, transmit, validate, process, archive, and disseminate data. The initial thrust will be on data base development in the highest priority science elements and

strengthening the infrastructure required to process, manage, and improve access to the great variety of ground- and space-based observations.

The key data management questions with policy implications include:

(1) ***How can the data handling and access capabilities be best organized and strengthened?***

Data management systems for global change must be able to accept and archive dissimilar types of data collected from different data collection systems , i.e., both ground- and space-based data by different organizations in different formats and on different media.

Interactions among CES agencies through the Interagency Working Group on Data Management for Global Change and with the science community have begun to facilitate improved access to data and data handling capabilities. A major problem facing scientists attempting to use global change data sets is that it is extremely difficult to find out who has what data and how good the data are. Using existing facilities, NASA, NOAA, NSF, DOE, and DOI will continue to develop and expand a Master Directory for Global Change Data by linking with a common architecture, directories, catalogs, and inventories of data in all global change science elements. Hundreds of global change data sets already have been documented and entered.

Studies have been initiated to develop archives with improved quality control, documentation, and ease of access to satellite data, including formation of the EOS Data and Information System (NASA, NOAA and DOI), and procedures are being developed for better distribution of digital data bases. Access to and assimilation of the DOD environmental data bases are being addressed. Bilateral agreements have been signed between NASA and NOAA and between NASA and

USGS for the development of data systems to manage satellite data. The exchange of satellite information between NASA, NOAA, European Space Agency (ESA), Canada, and Japan has been instituted. NASA and NOAA are gathering relevant foreign data to combine with U.S. data.

(2) ***How can the agencies build the data sets needed to facilitate early results from the Program?***

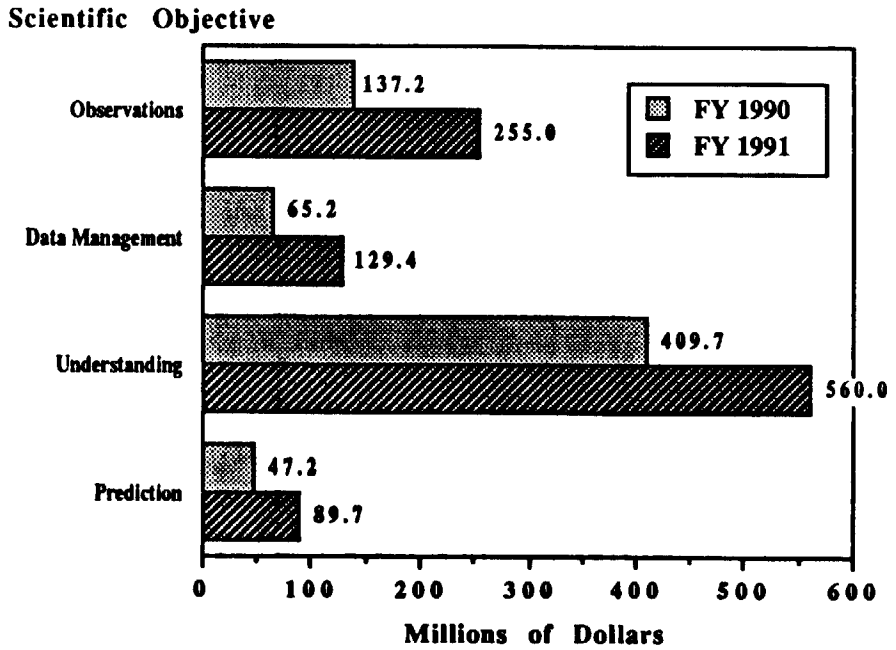
Long-term global measurements must routinely be supported by documentation regarding instrument calibrations, coverage, sampling, data editing, data reduction algorithms, including ancillary data, algorithm validation, assimilation or analysis procedures, and correlative measurements.

Many ongoing and new research programs contribute to the task of developing integrated global-scale satellite and *in situ* data sets that will support model development including the development of data bases in support of: biological responses to climate, abrupt climate change, anthropogenic forces in global change, long-term ecological research, studies of ecosystem stress, land-surface data, fire severity and occurrence, sea surface temperature fields, and regional ecosystem variables that are sensitive to global change. (All CES agencies are involved in one or more of these activities.) DOE will support a critical review of data for climate modeling, and NSF will support a geosystems data base activity that includes the development and quality control of model-generated data sets. On a priority basis, data sets are being extended into the past, both to document global change and to test and validate diagnostic and predictive models. NOAA and NSF data management elements provide resources for the development of historical and paleo data bases. DOE and DOI have similarly focused programs.

Budget by Scientific Objective

Figure 3 shows the FY 1990 enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by scientific objective: observations, data management, understanding, and prediction. These budgets reflect a balance between each of the scientific objectives, with a strong commitment to data management.

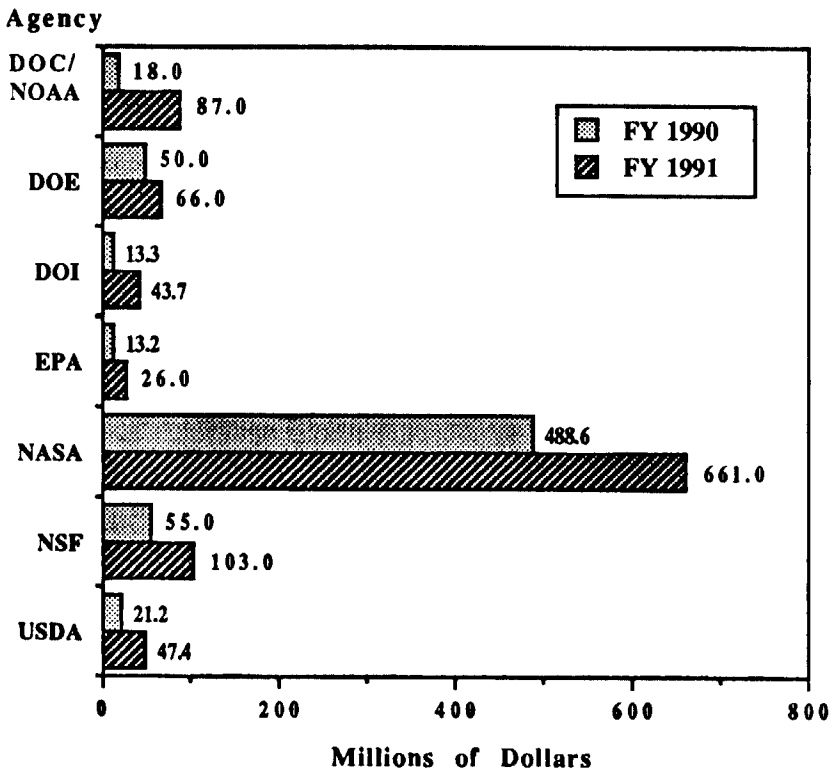
Figure 3
U.S. Global Change Research Program Budget by Scientific Objective



Budget by Agency

Figure 4 shows the FY 199O enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by agency. The individual agency efforts build upon their respective scientific and technical strengths.

Figure 4
U.S. Global Change Research Program Budget by Agency



National Oceanic and Atmospheric Administration (NOAA). In FY 1991, NOAA has proposed an $87 million Climate and Global Change Program in support of the U.S. Global Change Research Program. This represents a $69 million or 383 percent increase above the FY 1990 level. The FY 1991 NOAA contribution involves enhancements to ongoing efforts in: operational *in situ* and satellite observation programs with an emphasis on oceanic and atmospheric dynamics (including sea level), circulation, and chemistry; focused research on ocean-atmosphere interactions, the global hydrological cycle, the role of oceanic circulation and biogeochemical dynamics in climate change, atmospheric trace gas/climate interactions, and the response of marine resources to climate change and related stresses; and programs to improve climate modeling, prediction, and information management capabilities.

Department of Energy (DOE). In FY 1991, DOE has proposed a $66 million budget for global change research, a $16 million or 32 percent increase above the FY 1990 level. The DOE maintains a research program directed at the impact of energy production and use on the global Earth system by focusing primarily on climate, atmosphere, ocean, and ecosystem responses. DOE will augment research on climate modeling; studies of carbon dioxide sources in the atmosphere, oceans, and land; impacts on vegetation and ecosystems; and research efforts to quantitatively describe the radiative balance and the cloud-climate feedback in the atmosphere. New initiatives focus on critical data needs for global change research and the climatic variables that may serve as indicators of global change; and on funding to provide education and training to the next generation of scientists.

Department of the Interior (DOI). In FY 1991, DOI has proposed a $43.7 million budget for global change research, a $30.4 million or 229 percent increase above the FY 1990 level. DOI efforts include studies of: paleoclimates; interaction and sensitivity of hydrologic, ecological, and landscape systems with climate; arid, polar, and coastal regions and systems; volcano-atmosphere interactions; methane hydrates; changing

land surface characteristics; ocean heat fluxes; social, environmental, and economic consequences of global change including human activities, water resources, biological species variation, and land management; and carbon cycle variation studies; as well as archiving and distributing space- and land-based Earth science data.

Environmental Protection Agency (EPA). In FY 1991, EPA has proposed $26 million for global change research, an increase of $12.8 million or 97 percent above the FY 1990 level. EPA's research efforts are focused on evaluating the processes and quantifying the relative contributions of anthropogenic and biological sources of trace gases, quantifying and modeling the consequences of climate change on ecosystems and their subsequent feedback to the atmosphere, and the interaction of trace gases in the atmosphere. Special emphasis will be given to climate sensitive regions, e.g., tundra, wetlands and forests. EPA's research will help provide the process-level understanding and modeling capabilities to predict global change.

National Aeronautics and Space Administration (NASA). In FY 1991, NASA has proposed $661 million for global change research, an increase of $172.4 million or 35 percent above the FY 1990 level. NASA research efforts are primarily focused on space-based studies of the Earth as an integrated system. These activities include ongoing research and satellite programs (e.g., the Upper Atmosphere Research Satellite, Ocean Topography Experiment, etc.) that are important precursors to the FY 1991 initiatives: Earth Probes (a series of satellite measurements prior to EOS to monitor atmospheric ozone, ocean color, precipitation in the tropics, and ocean surface winds) and the Earth Observing System (EOS). EOS will provide an integrated, comprehensive monitoring and data management program of simultaneous measurements of key global change variables.

National Science Foundation (NSF). In FY 1991, NSF has proposed $103 million for global change research, an increase of $48 million or 87 percent above the FY 1990 level. NSF proposes to augment and initiate programs coordinated internationally to observe, understand, and model atmospheric, oceanic, terrestrial, and social processes and their coupled interactions. Studies include ocean circulation, ocean-atmosphere interactions, cloud-radiation interactions, global atmospheric chemistry, biogeochemical processes, land-sea interactions, past climate change, crustal and related processes impacting global change, ecosystems, solar processes, human dimensions of global change, data base research and development, and a multi-agency education initiative for global change.

United States Department of Agriculture (USDA). In FY 1991, USDA has proposed $47.4 million for global change research, an increase of $26.2 million or 124 percent above the FY 1990 level. USDA research efforts are focused on ground-based research programs studying agricultural, forest and range ecosystems as influenced by factors such as water balance, atmospheric deposition, plant responses to changes in atmospheric constituents, UV-B radiation and other global change variables. Some representative studies that will focus on agricultural effects on environmental variables will include mechanisms of methane generation and nitrous oxide release; soil properties including moisture, erosion, organic matter dynamics, nutrient fluxes, and microbes; relationship of global change to forest and range fires, insects, and plant pathogens; and agricultural management systems.

Budget by Federal Budget Function

Scientific, environmental, energy, and agricultural resources are vital to the health of our Nation. Table 3 shows the FY 1990 enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by Federal Budget Function. In FY 1991, significant increases above FY 1990 levels are proposed for each budget function. The U.S. Global Change Research Program must be viewed as a single integrated research effort with its success dependent upon cooperation and contributions from each of the individual agency programs.

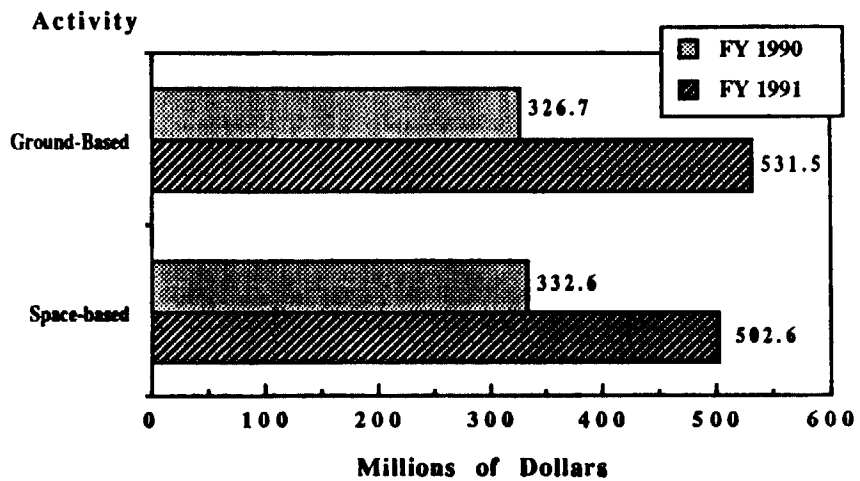
Table 3
FY 1990 - 1991 U.S. Global Change Research Program by Budget Function
(Dollars in Millions)

Budget Function	Budget Function Number	1990	1991
TOTAL		659.3	1034.1
General Science, Space and Technology	250	543.6	764.0
NASA		488.6	661.0
NSF		55.0	103.0
Energy (DOE)	270	50.0	66.0
Natural Resources and Environment	300	44.5	156.7
DOI		13.3	43.7
EPA		13.2	26.0
DOC / NOAA		18.0	87.0
Agriculture (USDA)	350	21.2	47.4

Budget by Ground- and Space-Based Research

Figure 5 shows the FY 1990 enacted and FY 1991 proposed budgets for the U.S. Global Change Research Program by space- and ground-based research activities. Maintaining an appropriate balance between ground- and space-based research programs is essential for a successful U.S. Global Change Research Program. *In situ* and theoretical studies of physical, chemical, biological, and geological processes must be complemented by a comprehensive space-based program to provide the global observations of key environmental variables. The combination of ground- and space-based measurements is required given the temporal and spatial variability of the systems being studied, and the need to scale the processes occurring at the local level to the regional and global levels. The ground-based program is essential to interpret some of the global satellite observations (e.g., long-term trends), as well as to obtain scientific information not attainable from space (e.g., trace gas fluxes). Both types of program need to be strongly supported, and the FY 1991 budget reflects a reasonable balance.

Figure 5
U.S. Global Change Research Program Budget by Ground- and Space-Based Programs



Ground-based: The FY 1991 request for the ground-based program is $531.5 million, a $204.8 million or 63 percent increase over the FY 1990 level. The budgets of NOAA, DOE, DOI, EPA, NASA, NSF, and USDA include support for a broad range of ground-based and modeling research activities. The activities range from small individual investigator research programs to participation in complex international scientific projects. The budgets would initiate multi-agency research thrusts in several critical areas including: the role of the oceans and terrestrial biosphere in trace gas fluxes; the exchange of energy between the oceans and atmosphere; the cycling of water throughout the Earth system; and expanded monitoring of responses to global change, such as sea level.

Space-based: The FY 1991 request for space-based programs is $502.6 million, a $170.0 million or 51 percent increase over the FY 1990 level. The NASA budget includes continued support for TOPEX and UARS, as well as the Earth Probes and EOS initiatives. The TOPEX, UARS, and Earth Probes missions will provide key global measurements, prior to the EOS era that starts in late 1997, including stratospheric composition; surface topography of the global oceans and sea surface wind velocity in order to advance the understanding of ocean circulation; rainfall in the tropics in order to determine the role of tropical precipitation in climate; and ocean color to improve the understanding of ocean productivity. EOS will provide an integrated, comprehensive monitoring program of simultaneous measurements of key global change variables, coupled with a comprehensive data and information system.

U.S. scientific agencies are playing a key role in a number of interdisciplinary international scientific programs involving the land, oceans, and atmosphere, and interactions between them, that require a combination of ground- and space-based measurements for successful implementation. These programs include: World Ocean Circulation Experiment; Tropical Ocean - Global Atmosphere; Global Ocean Flux Studies; Global Ocean Ecosytems Dynamics; Global Energy and Water Cycle Experiment; Global Tropospheric Chemistry Program; International Satellite Cloud Climatology Program; and International Satellite Land Surface Climatology Program.

The Carbon Cycle: An Example of Interdisciplinary Research

Modification of the global carbon cycle by human activities spans both science and policy concerns. This section of the report presents a case study of how the U.S. Global Change Research Program approaches a complex multidisciplinary research area like the carbon cycle.

Policy Needs

Emission of carbon dioxide from the combustion of fossil fuels and changes in land-use practices, and of methane from cattle, rice paddies, permafrost, natural wetlands, gas hydrates, and natural gas production are partly responsible for perturbation of the carbon cycle. Changes in the carbon cycle may affect regional and global climate, the chemistry of the atmosphere, the hydrologic cycle, and the productivity and functioning of ecosystems. Consequently, prudent environmental policy formulation will require a solid scientific understanding of how the carbon cycle varies naturally, how human activities change it, and how it might respond to future changes in environmental conditions.

Scientific Background

Atmospheric carbon dioxide is a radiatively active trace gas with concentrations 25 percent greater now than in the pre-industrial era (prior to 1850) and increasing at about 0.4 percent annually because of human activities. Annual anthropogenic emissions of carbon dioxide are currently about 5.5 billion metric tons from fossil fuel combustion, plus an additional 0.8 to 3.0 billion metric tons from tropical deforestation. Over the past century, fossil fuel use and cement manufacturing released about 200 billion metric tons of carbon into the atmosphere. In the same time period, land-use changes (primarily deforestation) may have released as much as an additional 115 billion metric tons of carbon. However, only 130

billion metric tons of these combined releases remain in the atmosphere. A critical question concerning the global carbon balance is, "What has happened to the remaining carbon dioxide and what will happen to it in the future?"

The natural fluxes of carbon dioxide into and out of the atmosphere from the oceans and terrestrial biosphere are an order of magnitude greater than the anthropogenic fluxes. The oceans, which contain about 50 times more carbon than does the atmosphere, are known to be an important long-term sink for carbon from the atmosphere. In addition, while terrestrial vegetation has always assimilated atmospheric carbon dioxide by photosynthesis, it recently has been suggested that vegetation and soils at northern mid-latitudes may be becoming more effective in sequestering carbon from the atmosphere because of either changes in land management (e.g., reforestation) or because the increasing atmospheric carbon dioxide concentrations may be stimulating plant productivity. These oceanic, terrestrial, biogeochemical, and ecological processes ultimately determine the fate of carbon dioxide from human activities. However, uncertainties in the knowledge of the magnitude of the oceanic and terrestrial sinks limit the accuracy of forecasts of the future fraction of "anthropogenic" carbon dioxide that will remain in the atmosphere.

Atmospheric methane is a radiatively and chemically active trace gas whose concentration is now a factor of two greater than it was in the pre-industrial era and is increasing at about 1 percent annually, presumably because of human activities. The atmospheric abundance of methane is controlled by emissions from oxygen-deficient sources such as natural wetlands, permafrost and gas hydrates, rice cultivation, biomass burning, cattle, natural gas venting, and removal by atmospheric chemical reactions.

Uncertainties in the knowledge of the magnitude of the individual sources and sinks of carbon dioxide and methane severely limit the accuracy of forecasts of their future atmospheric concentrations.

Required Understanding

Biological and physical processes control the uptake and release of carbon by the oceans, and ecosystem dynamics are equally important on land. Economic and human factors dictate the magnitude of fossil fuel emission and the intensity of land disturbance. The task of predicting future abundances of atmospheric carbon dioxide, methane, and other carbon-containing gases requires scientific information, spanning numerous scientific disciplines, including: the exchange of carbon dioxide between the oceans and the atmosphere; the exchange of carbon dioxide and total carbon between the shelves and open oceans, and between the surface waters, deep ocean and sediments; the exchange of gases between terrestrial ecosystems and the atmosphere; the storage and cycling of carbon within terrestrial ecosystems; the extent and ecological state of terrestrial and aquatic ecosystems; atmospheric distributions and transformations of gases; paleocarbon budgets; and the influence of human choices on the carbon cycle.

U. S. Global Change Research Program Approach

After evaluating the policy needs, scientific background, and required understanding, a responsive, multidisciplinary research effort was developed. The box on page 54 gives examples of specific U.S. Global Change Research Program activities related to the carbon cycle. Synthesis and integration of results obtained by investigators working within their numerous disciplines is a critical challenge guiding the U.S. Global Change Research Program. This diversity of research, data collection, and modeling activities is typical of global change research.

Special Issues

The CES has addressed several issues that are important to the success of the U.S. Global Change Research Program. The sections below describe those issues and the approach that CES has taken.

Education

The science of global change is complex and inherently multidisciplinary. While unraveling answers to scientific questions undoubtedly will require new approaches and technology, another important concern is the development of the human resources and scientific talent to conduct multidisciplinary global change research.

To address this need NSF and DOE will initiate human resources programs in FY 1991 that will annually support several hundred postdoctoral appointments, graduate students, and undergraduate students as research participants, as well as several summer institutes on interdisciplinary global change research problems. The NSF program will be managed by representatives from each of the CES agencies. Training opportunities, both in the U.S. and abroad, will include: (i) support at the individual project level, (ii) training centered at major research centers or technology centers, and (iii) opportunities for students to pursue training at institutions of their choice. The DOE program will encourage basic training at universities offering interdisciplinary programs and operational experience in team research at national laboratories and other science and technology centers. In addition, one component of the NASA EOS program is for educational scholarships.

Emerging Disciplines

The U.S. Global Change Research Program presented here should not be viewed as a full exposition of the details of the program in the outyears. The program will evolve as new projects are developed in response to scientific developments

and policy needs. Each of the U.S. scientific agencies has programs at various stages of planning, and furthermore, there are major scientific planning activities related to global change within U.S. (Committee on Global Change of the National Academy of Sciences) and international (e.g., the International Geosphere-Biosphere Programme [IGBP] of the International Council of Scientific Unions [ICSU], and the World Climate Research Programme [WCRP] of the World Meteorological Organization [WMO]) scientific communities that have not reached the point of submission to agencies for any formal consideration. Examples include work on paleontology, hydrology, experimental ecology, and human interactions.

International Dimension

The U.S. Global Change Research Program is founded on the premise that international cooperation and coordination are fundamental to the scientific planning and the implementation of the entire Program. Research programs like the IGBP and the WCRP are truly international in scope and in design. The complex scientific agenda and the infrastructure needed to address the programs outlined here require a careful assessment and integration of the Program's components with programs of other governments; intergovernmental bodies (e.g., U.N. bodies such as the IPCC); and international non-governmental science coordinating and facilitating mechanisms (e.g., ICSU).

There is no "international" budget item included in the U.S. Global Change Research Program because it is integral to each project element. A major CES coordinating effort has been initiated with ICSU and the international scientific community, the intergovernmental organizations, and CES-like bodies in other countries. During 1990, it is expected that an integrating infrastructure will begin to evolve; will be endorsed by the various participating agencies, organizations, and institutions; and will involve to some extent the private and industrial sector. Bilateral and multilateral research agreements and programs between the U.S. and other countries are an essential part of this international framework.

EOS: The Earth Observing System

To understand global change and the increasing demands of human activity, it is essential that we document and comprehend how the Earth works as a system. The international scientific community is organizing research efforts to advance our knowledge of both natural and human-induced global change. The U.S. Global Change Research Program, a consensus interagency plan, defines the U.S. element of those efforts.

Mission to Planet Earth, the central NASA contribution to the U.S. Global Change Research Program, includes two proposed initiatives in the FY 1991 Federal budget: the Earth Observing System (EOS) and Earth Probes.

EOS consists of a space-based observing system, a Data and Information System (EOSDIS), and a scientific research program. It represents the initiation of a comprehensive, global observing system with broad and high-resolution spectral and spatial, as well as long-term temporal, coverage of the Earth. The space component will consist of two series of polar-orbiting platforms, with launch of the first platform in FY 1998. EOS will be supplemented by companion European and Japanese platforms, as well as the continuing operational environmental satellites.

EOS will continue and integrate the measurements now being taken by short-term research missions. It will provide the first coordinated simultaneous measurements of the interactions of the atmosphere, oceans, solid earth, and hydrologic and biogeochemical cycles.

Earth Probes will provide a focus on observing specific Earth processes where smaller platforms and/or different orbits from EOS are required. In addition to complementing EOS, Earth Probes will provide critical near-term observations.

Development of EOSDIS will begin immediately to support the research and analysis of both existing data and those to come from the near-term missions. EOSDIS will be a state-of-the-art information system to foster rapid and easy access for users.

This document presents EOS, Earth Probes, and related precursor research missions—all in the context of supporting the U.S. Global Change Research Program. For additional information, Pre-EOS and EOS Reference Handbooks are available which provide in-depth information on candidate instruments, their measurements, and the Data and Information System.

On the cover: the EOS-A (left) and -B (right) polar platforms. The five discs show (left to right): variable sea-surface topography, sea-surface temperature, a composite of ocean chlorophyll concentration and terrestrial vegetation index, mean cloud cover, and stratospheric ozone.

Understanding The Earth As A System

We live on a planet of extraordinary complexity; the presence of an atmosphere and oceans with the right chemical composition on a solid planet has supported the development of an abundant diversity of life. Throughout geologic history, the atmosphere, oceans, and land have interacted to produce global environmental change to which life has contributed and adapted. Today, one species of life, humankind, through increasing population and quest for improved quality of life, has developed the capability of changing our global environment in ways that we are only beginning to perceive, but do not fully understand.

In some cases, such as the depletion of the Earth's energy and mineral resources, the effects of human activity are obvious. In other cases, such as the alteration of atmospheric chemical composition, the processes of change are difficult to document, and their consequences harder to foresee. Moreover, the effects of many human-induced changes cannot readily be distinguished from the results of natural change over time periods of decades to centuries.

We now know that we have embarked on a global experiment, but we do not know the consequences. Model predictions suggest that the Earth should be warming in response to increasing carbon dioxide and other gases in the atmosphere, but observations are ambiguous. Is the signal lost in the noise of natural climate variability, or are there other processes at work? Until we more completely understand the Earth system, we will not be able to answer such crucial questions.

The oceans, atmosphere, and ice-covered regions of the globe are now recognized to be closely coupled in shaping the Earth's weather and climate. Both terrestrial and oceanic biota are recognized as exerting a major influence on global climate and the chemical cycles important to life. But the fundamental questions about how the Earth system works remain unanswered.

Over the past 40 years, our view of the solid Earth has been dramatically transformed. The earlier notion of a placid, static globe has been replaced by the dynamism of plate tectonics. Patterns of mountain-building, volcanism, and earthquake activity all fit consistently into this new view.

It is essential that we understand how components of this system interact—from the short time scales of weather systems to the millennia of geological time—and how we affect these interactions. Until we have that understanding, we will not be able to predict how human activities will change the environment.

A global view of the Earth's biosphere. Shown are three-year composite images of ocean chlorophyll concentration (increasing from purple to red) and land vegetation index (increasing from tan to green), derived from NASA's Nimbus-7 Coastal Zone Color and the NOAA-7 Advanced Very High Resolution Radiometer, respectively.

A Plan For Action

The demonstrated human role in global change requires that we develop a comprehensive program of Earth studies that transcends traditional disciplinary boundaries. Our goal is to obtain a scientific understanding of the Earth as a system, from which we hope to develop a capability to predict future change.

The key to understanding is accurate observations and modelling of the crucial interacting processes. Such observations of the state of the Earth are critical for providing a system for early warnings of change. To obtain that basic information, we need appropriate instruments deployed both on the Earth's surface and in space. Satellite remote sensing provides global and long-term continuous measurements for monitoring the entire planet. Surface-based measurements are required both to validate the space-based observations, to provide more detailed studies, and to observe those processes not accessible from space.

The international scientific community is developing programs to address global change. The World Climate Research Programme, sponsored by the International Council of Scientific Unions (ICSU) and the World Meteorological Organization, focuses on physical aspects of climate systems: the role of clouds and radiation, ocean circulation, air-sea interaction, and the effects of global water and energy budgets on climate. ICSU has established the International Geosphere-Biosphere Programme to describe and understand the interactive chemical and biological processes that regulate the total Earth system.

In response to the scientific challenge and a national perception that the U.S. must take a leadership role in global change research, a federal interagency Committee on Earth Sciences was formed under the President's Science Advisor to develop a plan for action. With remarkable agreement and clear consensus, representatives of thirteen federal agencies have produced the first U.S. Strategy for Global Change Research.

The integrating priorities of this program are to document change in the Earth System using observational programs and data management systems, to carry out focused studies on controlling processes to improve our understanding, and to develop integrated conceptual and predictive models.

For the first half of the 1990s, space-borne contributions to the Global Change Research Program will come from the missions described below. These include the initiation of NASA's Earth Probes as well as the EOS Data and Information System (EOSDIS) which will support study of available satellite data. The launch of the first of NASA's EOS polar platforms is in FY 1998 and will mark the beginning of a comprehensive and long-term measurement system.

5

Schematic representation showing how interdisciplinary components of NASA's EOS science program relate to the corresponding science priorities of the U.S. Global Change Research Program.

Focused Near-Term Observations

Earth remote sensing has evolved from developing and demonstrating technology to focusing on specific research and operational topics. For example, NASA's Seasat and the series of Nimbus satellites have demonstrated the utility of active and passive microwave systems for characterizing the oceans and atmosphere.

Building on the lessons learned, two research missions under development are the Upper Atmosphere Research Satellite (UARS) and TOPEX/Poseidon, focused on atmospheric chemistry and oceanic circulation, respectively. There are also sensors for short-term deployment from the Space Shuttle: Shuttle Imaging Radar (SIR), Shuttle Solar Backscatter Ultraviolet sensor (SSBUV), and Atmospheric Laboratory for Applications and Science (ATLAS). These address the development and utilization of synthetic aperture radar, accurate measurements of ozone in the upper atmosphere for cross-calibration purposes, and observations of solar influences on atmospheric chemistry. Finally, accurate tracking of the two laser geodynamics satellites (LAGEOS-1, -2) provides gravity and geodetic data.

In addition, the U.S. Department of Defense has flown an altimetric satellite, GEOSAT, and plans another, SALT, for observing oceanic circulation. Foreign missions include the European Remote Sensing satellite (ERS-1), for ocean observations; Japanese Earth Resources Satellite (JERS-1), for global mapping of resources; Canadian Radarsat, for sea-ice mapping; and Japanese Advanced Earth Observing Satellite (ADEOS), which will include two of NASA's proposed Earth Probe sensors.

Included in NASA's proposed Earth Probes are sensors destined for flights of opportunity: Total Ozone Mapping Sensor (TOMS) to provide interim ozone observations until the flight of EOS, Sea-viewing Wide-Field Sensor (SeaWiFS) to provide improved observations of oceanic chlorophyll, and Scatterometer (NSCAT) to provide marine surface winds. The Tropical Rainfall Measuring Mission (TRMM) will provide the first spaceborne measurements of low-latitude rainfall.

Throughout the first half of the 1990s, the research missions discussed below will provide remotely sensed data for the Global Change Research Program. They will be complemented by operational missions currently consisting of geosynchronous and polar-orbiting satellites for weather forecasting and land measurements. Simultaneously, the EOS Data and Information System will provide a means for accessing data from these missions and integrating them in global change studies—all in preparation for the comprehensive Earth Observing System of the second half of the 1990s.

7

This table shows the distribution of Earth-related missions in the pre-EOS era. Included are those proposed Earth Probes which have been defined.

Oceanic Circulation, Atmospheric Chemistry

Two major missions, each addressing a specific question relating to global change, are under development for launch in the early 1990s. TOPEX/Poseidon is focused on oceanic circulation and the Upper Atmosphere Research Satellite (UARS) on atmospheric chemistry.

TOPEX/Poseidon. The large-scale movement of water in the ocean affects climate by transporting heat from the equator to the poles. This oceanic circulation is one of the weak links in our understanding of the physical climate system. Surface and deep currents, upwelling, and bottom-water formation are involved. But to observe this complex system has proved extraordinarily difficult with conventional means. To achieve a global synoptic view of the circulation will require satellite measurements as well as *in situ* studies. NASA and France's Centre National D'Etudes Spatiales have designed a joint mission, TOPEX/Poseidon, that will use a radar altimeter system deployed in an orbit specifically designed for precise measurements of broad-scale ocean surface currents unobtainable via shipboard observations. It will be launched in 1992 on an Ariane rocket.

TOPEX/Poseidon will give accurate measurements of currents and tides, but with only a single altimeter, it cannot resolve the smaller-scale ocean eddies which are also important in ocean heat transport and biological processes. With at least two altimeters flying on different satellites in the EOS era, the broad spectrum of oceanic circulation can be monitored.

UARS. Major questions of atmospheric chemistry remain unanswered despite having received much attention in recent years: What causes ozone variations? How are the chemical, radiative, and dynamic processes of the stratosphere coupled? UARS, planned for launch in 1991, will gather data related to the chemistry, dynamics, and energetics of the ozone layer. UARS data will be used to study energy input, stratospheric photochemistry, and upper atmospheric circulation. UARS will help us understand and predict how the nitrogen and chlorine cycles—and the nitrous oxides and halocarbons which maintain them—relate to ozone balance. It will also observe diurnal variations in short-lived stratospheric chemical species important to ozone destruction.

UARS, primarily focused on the upper atmosphere, will only provide a very limited set of companion measurements in the troposphere. Moreover, UARS, like most research missions, has a relatively short (two to five years) lifetime. EOS will provide continuing measurements, as well as more complete coverage of chemical species in both the stratosphere and troposphere.

9

Sea-level variability measured by the U.S. Navy's GEOSAT over a two-year period revealing fluctuations in the western boundary currents and Antarctic Circumpolar Current (increasing to red-yellow). The smaller images show two atmospheric constituents that were measured by the LIMS sensor aboard Nimbus-7 during the winter of 1979: left, nitrogen dioxide; right, nitric acid (increasing from blue to red).

Research Use Of Operational Data

Initial pictures of weather from space were produced from a U.S. TIROS satellite in 1960. Today, the polar-orbiting and geostationary environmental satellites of the National Oceanic and Atmospheric Administration, the Defense Meteorological Satellite Program (DMSP), the commercial venture Eosat, and their counterparts around the world provide valuable, real-time information about the changes in the world's weather and land surface. In addition, the operational satellites yield information on climate variables, including surface temperatures, wind velocities, land cover and usage patterns, snow cover and sea ice, cloudiness, global precipitation, and the Earth's radiation budget. This operational system works well: the real-time data provide continual warning of short-term weather hazards such as hurricanes, storms, and other extreme events.

These data have provided a tantalizing first view of the workings of the components of the Earth system. Moreover, the data collected by the operational systems have the potential for providing useful information on global change. They constitute a record, now over a decade long, of baseline information against which global change can be measured. In addition, new data products are being developed to exploit the data for use in longer-term climate studies.

At the same time, since the systems are driven by operational and commercial requirements, the full use of the data for research on global change has been limited. The spectral coverage of the environmental and Landsat systems is limited, the repeat coverage of Landsat is infrequent and the commercial viability and hence continuity of Landsat is in doubt. It has not been easy for researchers to access data, either for reasons of cost or because data do not exist or are not available in formats that can be easily used.

The next logical step for these systems is to address long-term calibration and validation issues, generate research quality products, and make these products available to a wide variety of users in a manner compatible with the EOS Data and Information System. In this way, the research community will have a means to work with large data sets as it prepares for the new research missions and EOS itself.

It is essential that the operational satellite observations extend into the future in order that the baseline information continue. With the generation of research quality products and easy access to archives, the operational systems can significantly complement the research missions, Earth Probes, and EOS to provide the comprehensive data set necessary to document and understand global change.

11

The larger image from NOAA's GOES shows cloud patterns on September 22, 1989, as Hurricane Hugo hit the coast of South Carolina. The smaller visible image from DOD's DMSP shows prominent sea-ice features and wind rows in the Bering Sea on March [illegible], 1989.

EARTH PROBES: BIOGEOCHEMISTRY

The Ozone Hole, Ocean Productivity

Earth Probes are being proposed to obtain near-term observations of specific Earth processes prior to EOS, as well as to complement EOS in those cases where smaller platforms and/or orbits other than EOS are required. Earth Probes are scheduled to begin flying in 1991 with a satellite launch every two to three years.

TOMS. The Total Ozone Mapping Spectrometer (TOMS), the first Earth Probe, will measure atmospheric ozone. The habitability of the Earth depends on maintaining the ozone layer, which absorbs harmful ultraviolet light. We now know that ozone depletion is caused by complex, coupled chemical reactions. In the early 1970s, a warning was sounded that the chlorofluorocarbons used in widespread applications could cause depletion of the ozone layer. The TOMS sensor on Nimbus-7 has provided a continuous global record of ozone over the full depth of the atmosphere since 1978, but the instrument is now reaching the end of its useful life. To continue these measurements, NASA has made arrangements for a TOMS instrument to fly on a Soviet Meteor-3 Satellite and on the Japanese Advanced Earth Observation satellite; a low-cost U.S. satellite to carry a TOMS payload is also being designed. Thereafter, instruments to monitor ozone will be carried on future NOAA satellites.

SeaWiFS. One of the next Earth Probes is the Sea-viewing Wide-Field Sensor (SeaWiFS), an ocean color scanner. Biological processes in the ocean are critical to biogeochemical cycles. In the upper ocean, primary production by phytoplankton is a key parameter in regulating carbon flux in the sea. Thus, it is essential to understand its magnitude and variability. However, present uncertainties in estimates of oceanic primary production are larger than the annual rate of atmospheric carbon dioxide increase.

To address this need, NASA has defined performance specifications for the SeaWiFS sensor which will measure ocean color related to phytoplankton chlorophyll. SeaWiFS will be able to measure chlorophyll in the open ocean where the signal is low, distinguish between phytoplankton pigments and sediment in coastal water, and make the necessary atmospheric corrections. These data will provide the first estimates of the mean and variable rates of primary production in the world oceans.

Instruments planned for EOS will continue previous ocean color time series. In addition, with their higher spectral resolution, they will have important new capabilities that will accurately resolve photosynthetic potential and plankton types, thus increasing our capability to study the interactions of marine ecosystems and global change.

13

Ozone concentration (smaller image) from TOMS showing the ozone hole for October 1989 (increasing from purple-blue to yellow-red). Four-year composite of chlorophyll concentration (larger) from CZCS (increasing from purple-green to yellow-red); also shown is the typical minimal extent of sea ice in summer (white).

EARTH PROBES: PHYSICAL CLIMATE

Marine Winds, Tropical Rain

In the tropical Pacific Ocean, the changing winds, rainfall, and heat from the ocean are the signals and drivers of El Niño, the periodic climate anomaly that has global implications. Accordingly, NASA is developing systems to measure marine surface winds and rain as part of its Earth Probes program.

NSCAT. Winds drive ocean currents and modulate the fluxes of heat, moisture, gases, and particulates between the air and the sea. Thus, knowledge of ocean surface winds is crucial for understanding the ocean-atmosphere coupling. A better understanding of the marine boundary layer and troposphere will also improve numerical weather predictions.

At present, most wind observations over the oceans come from ships, and the data are often inaccurate and geographically sparse. The NASA Scatterometer (NSCAT), an active radar system in a sun-synchronous orbit, can measure both wind speed and direction over at least 90 percent of the ice-free global oceans every two days. NSCAT is now being developed for space flight on the Japanese ADEOS satellite with launch in 1995. This flight schedule will allow an overlap with the extended mission of TOPEX/Poseidon, thus providing an estimate of the wind forcing and ocean current response.

The absence of a co-located microwave radiometer on ADEOS precludes correction of NSCAT data for contamination by atmospheric water or the identification of rain-induced errors, thus leading to subtle inaccuracies and geographical biases. EOS instrumentation will remedy these deficiencies, as well as continue the measurement series begun by NSCAT.

TRMM. The Tropical Rainfall Measuring Mission (TRMM), a joint effort between the U.S. and Japan, is being proposed to test the feasibility of using active and passive microwave data, together with visible and infrared, to derive rainfall amount and distribution between 35 degrees north and south latitude. In addition, some information about the vertical distribution of rain in thunderstorms will be obtained. TRMM seeks at least a three-year data set of monthly averaged rainfall. As part of EOS, an additional TRMM package is proposed for the Space Station in order to provide a decade of continuous observations.

TRMM data will be used directly in climate models that are critical to understanding global change. However, TRMM will not measure precipitation outside the tropics and subtropics, and it will have relatively large sampling errors over land. These problems will be partially alleviated by using the TRMM package on Space Station in conjunction with complementary sensors on the EOS polar platforms.

15

The larger image shows surface streamlines (white lines with arrows) and wind speeds (increasing from blue-purple to red-yellow) from the Seasat Scatterometer on September 14, 1978. The smaller shows 1988 Northern Hemisphere winter (top) and summer (bottom) estimates of total rainfall based on infrared observations from the geostationary weather satellites (increasing from red-yellow, through green-dark blue, to light-blue).

Integrated, Long-term Observations

Understanding global environmental change requires knowledge of the entire Earth system. A new concept, Earth System Science, has developed to describe how its components and their interactions have evolved, how they function, and how they may be expected to continue to evolve.

The ultimate goal of Earth System Science is to develop the capability to predict environmental changes, both natural and human-induced, that will occur in the future. Meeting this challenge for the next decade to century requires the integration of knowledge from the traditional disciplines and information from many different sources into a coherent view of the Earth system.

Earth remote sensing has matured as a result of technology development and utility demonstrations. But even as this has occurred, Earth science has continued to be organized along traditional disciplinary lines. With the understanding and experience which has grown within these disciplines, with new technology, and with the challenge of understanding Earth as a system, we are now ready to pursue Earth System Science.

We can now shift our focus from traditional disciplines toward interdisciplinary components of the Earth system as discussed in the following pages: the influence of clouds and radiation balance, role of oceans and atmosphere in heat transport, hydrologic and carbon cycles, changing composition of the atmosphere, and geological and geophysical processes.

EOS has been designed to meet observational needs of Earth System Science. It will operate for 15 years, a time period which encompasses a large span of major environmental change, ranging from several atmospheric biennial oscillations, three to five El Niños, and an entire solar cycle. It will provide a sufficiently large platform to accommodate appropriate suites of sensors so that multiple views of the same location on Earth at the same time will avoid atmospheric-induced uncertainties. It will provide broad and high-resolution spectral and spatial coverage. It will feature a fixed payload for the duration, so that it can provide a consistent set of observations.

One particular strength of EOS is that it will provide, for the first time, a long-term, simultaneous set of observations of the same phenomena on ever-increasing spatial scales (local, regional, global) that can be used to integrate and extrapolate our understanding of ecological and hydrological processes.

The EOS Data and Information System (EOSDIS) will not only provide access to EOS and appropriate complementary ground-based data, but will also support the research and analysis of data which exist today and which will come from pre-EOS missions.

16

Schematic representation of interdisciplinary components of NASA's EOS science program.

What Is The Influence Of Clouds?

The energy balance of the Earth's climate system is determined by the balance between absorbed and emitted radiation. For the Earth as a whole, and over long time periods, there is a near balance of net radiation at the top of the atmosphere. On shorter time scales, the variable distribution of heating and cooling provides the sources and sinks of energy which drive the circulation of the atmosphere and oceans.

Throughout the atmosphere, radiative heating and cooling compete with other processes such as evaporative cooling or latent heat release to determine the temperature. Radiation is also important in partitioning energy between the atmosphere and the continental surface and between the atmosphere and the oceans, thereby determining the extent to which the oceans moderate climate change. Over land, the solar flux received at the surface has a strong influence on the hydrologic cycle and the biosphere. To understand all of these processes we must monitor the parameters that govern the radiation balance.

The incoming solar radiation heats the atmosphere and the Earth's surface. The Earth and atmosphere cool by re-radiating a portion of the energy at much longer wavelengths. The difference in radiation at the top of the atmosphere and at the surface is the net radiative heating or cooling of the atmosphere. This difference can be monitored best from space.

The principal attributes of the atmosphere that affect the radiative fluxes must also be monitored to determine the processes that cause changes in the radiative balance. Such measurements have been made from space through the use of operational satellites and the Earth Radiation Budget Experiment. The results from these studies, only recently available, tend to confirm that low level clouds cause cooling through reflection of solar radiation whereas high level clouds cause heating through absorption and reflection of surface radiation. Further long-term measurements will be required to establish the validity of these initial conclusions.

EOS instruments will provide improved spatial resolution and high spectral resolution observations of clouds and more accurate profiles of atmospheric temperature and water vapor. They will also monitor cloud water vapor and precipitation. All of these observations contribute to improved measurement of surface temperature and moisture. Other EOS instruments will provide complete hemispherical coverage of the radiance pattern to provide data for new angular distribution models, improved fluxes and daily, global observations of stratospheric and tropospheric aerosol optical thicknesses.

18

These figures show results from the Earth Radiation Budget Experiment for January 1986 and include the combined effect of sunlight and infrared radiation. The smaller figure shows the net radiation for clear-sky conditions, where blue (magenta) represents the heat loss (gain) corresponding to the Northern (Southern) hemisphere winter (summer). In the larger figure, clouds have a net cooling (heating) effect over the blue-green (yellow-red-magenta) regions.

THE GLOBAL HYDROLOGIC CYCLE

What Governs Rainfall Patterns?

The existence of abundant water, an essential ingredient for life, is a primary difference between Earth and the other planets. Through the hydrologic cycle, water is an essential element of most processes that determine global climate change. The redistribution of heat that governs the Earth's climate depends largely on the transport, evaporation, condensation, and freezing of water, as well as the role of clouds and water vapor in the Earth's radiation balance. Water is a primary agent in shaping the landscape and in transporting sediments and nutrients. It is an essential part of all biogeochemical cycles and interacts strongly with vegetation. In the form of ice and snow cover, water affects the Earth's radiation balance, polar oceans, and sea level. Water supply governs the distribution and level of agriculture, energy production, and industry. Drought and floods are evident examples of the impact of water on societies. Despite the significance of water, our knowledge of the hydrologic cycle as part of the global, interacting system is meager.

In tropical and subtropical regions, clouds and precipitation are a major driving force for the circulation of the atmosphere. The Tropical Rainfall Measuring Mission (TRMM) and the efforts to establish a global precipitation climatology are the first steps in investigating one of the least known and most crucial elements of the global hydrologic cycle. But we are far from understanding how the hydrologic cycle will respond to a changing Earth system, or how water will influence the other components of the system.

Precipitation, soil moisture, atmospheric water vapor, clouds, snow pack, sea ice, polar glaciers, vegetation, temperature, and winds are each critical quantities needed to characterize the climate and hydrologic system. The very diversity of the effects of water in the Earth system have limited the development of a unified understanding of water. EOS will provide the first long-term, consistent global measurements of many of these key physical variables. The most important contribution of EOS will be the capability for simultaneous measurements necessary to investigate the processes which define the interactions and feedbacks within the hydrologic cycle.

A variety of EOS instruments will each contribute different components to our knowledge of physical climate and the hydrologic cycle. The global measurements and the process studies based on the simultaneous combination of EOS measurements are critical to understanding the central role of water in the Earth system.

22

This composite view (top) in the visible portion of the spectrum is based on data from NOAA's GOES-5 and European Meteosat-2 on July 4, 1983. Clouds are shown in greys, oceans blue, and land green to tan. Nimbus-7 microwave radiometer-derived estimates (bottom) of sea ice and snow cover for February 1983. Sea ice is white, permanent ice sheets purple, and depth of snow cover shades of blue.

CIRCULATION OF THE OCEANS AND ATMOSPHERE

How Is Heat Transported?

Atmospheric and oceanic circulations play a central role in the climate of the Earth. The atmosphere is driven by the radiation from the sun. The surface winds drive the oceanic circulation and influence the exchange of heat between the oceans and the atmosphere. The result is a complex interacting system of winds and currents which are a part of the climate system. As we try to understand and predict changing climate, improving our knowledge about the interaction between oceanic and atmospheric circulation is essential. For example, the heat content and time scales of motion in the oceans are larger than in the atmosphere. Thus, changing the storage of heat or the rate of formation of cold deep water in the oceans could substantially lessen the impact of a greenhouse effect. Similarly, the formation of sea ice in the polar regions can lead to changes in heat transport and deep-water formation which can have significant impacts on climate.

The best estimates of the heat flux by the atmosphere and oceans have been obtained by inference from the global radiation budget and atmospheric heat transport. Using these estimates, the oceans and atmosphere are found to transport roughly equal amounts of heat poleward. However, attempts to measure the oceanic heat transport directly have not succeeded in providing an accurate estimate. For many parts of the globe, particularly in the Southern Hemisphere, neither the magnitude nor the direction of the directly estimated heat transport is consistent with the inferred transport.

EOS, together with *in situ* measurements, will provide for the first time the necessary simultaneous observations for accurate estimation on a global scale of both the circulation and heat transport of the atmosphere and oceans. While operational satellites have given profiles of atmospheric temperature for almost two decades, EOS will provide the first simultaneous wind profiles on a global basis, which will improve estimates of the atmospheric heat transport. Similarly, the sea-surface temperature, sea-ice coverage, and surface oceanic circulation will be observed simultaneously by the radiometers and altimeters on EOS, leading to improved estimates of the heat exchange between the oceans and the atmosphere. By combining simultaneous observations from several EOS sensors, a better description of the complex interaction between the oceans and the atmosphere will be achieved. Coupled with numerical models, these measurements should greatly improve our ability to understand and predict the role of oceanic and atmospheric circulation in our changing climate.

20

The mean surface temperature (top) for June 1988 as obtained from the infrared and microwave radiometers (HIRS/MSU) aboard the NOAA series of meteorological satellites (increasing from blue-yellow to red). In the lower figure, the mean dynamic topography obtained from the Geosat satellite shows the large-scale average ocean circulation; streamlines are clockwise around the higher elevations (yellow-red) in the Northern Hemisphere.

THE GLOBAL CARBON CYCLE

What Controls Atmospheric CO_2?

Since 1850, atmospheric carbon dioxide has increased by 25 percent and atmospheric methane by more than 100 percent. Though the changing carbon cycle has been studied for a long time, we remain uncertain about many of the controlling processes and the relative role of the terrestrial ecosystem versus the oceans in sequestering carbon. Hence we cannot predict future trends and effects. The exchange of carbon between the atmosphere, terrestrial biosphere, and oceans as well as the magnitude of the major carbon reservoirs are central issues in understanding the global carbon cycle. If climate changes, how will these exchanges be affected? Will the oceans take up less carbon dioxide or more? Will the terrestrial feedbacks be positive or negative? What will happen to the major storage reservoirs of carbon? These are vital issues for society.

Large uncertainties in our understanding of the carbon cycle are related to questions such as: How much carbon dioxide is being released from vegetation and soils as a result of natural changes and deforestation? How much carbon dioxide is being taken up by the oceans? What is the rate of carbon transfer between the atmosphere and terrestrial ecosystems? The sources for increased methane emissions to the atmosphere need to be identified and quantified.

Current operational observing systems can provide estimates of the rate of deforestation, but coverage is incomplete because of cloud cover problems in the tropics. These systems have extremely restricted spectral resolution and cannot discriminate subtle changes in disturbed ecosystems. EOS instruments will provide needed global coverage of ecosystem states. The synthetic aperture radar, planned to fly on a separate spacecraft, will have the ability to penetrate clouds and forest canopies to characterize forest biomass and moisture status with high resolution maps. This information will be used to infer global productivity patterns, both on the land and in the ocean, another important aspect of the global carbon cycle.

The net flux of atmospheric carbon dioxide into the oceans remains uncertain. The rate of carbon uptake by the oceans is controlled by a complex interaction of ocean biology, chemistry, and circulation. Over 99 percent of all biologically incorporated carbon is buried in ocean sediments. Thus, small changes in oceanic primary productivity can have a major impact on the partitioning of carbon dioxide in the global carbon cycle. EOS instruments will allow dramatically improved estimates of biological activity in the upper ocean, the sea-surface state, and the circulation. The data will be used to make improved models of the carbon cycle.

24

The figures on the right compare 1989 March (top) and October (bottom) vegetation index patterns (increasing from tan to purple) based on data from the NOAA AVHRR. The figures on the left compare 1979 spring (top) and winter (bottom) phytoplankton chlorophyll concentrations (increasing from purple to yellow-red) based on data from the Nimbus-7 CZCS.

OZONE AND ATMOSPHERIC CHEMISTRY

How Is The Atmosphere Changing?

The changing chemical composition of the atmosphere in recent years has been a dramatic signal of global change. The principal changes observed have been the reduction of stratospheric ozone by chlorofluorocarbons and the buildup of greenhouse gases in the lower atmosphere.

The chemistry of the atmosphere is central to understanding these critical environmental processes, and ozone is at the center of atmospheric chemistry. Ozone is a protective shield in the stratosphere and it is being depleted by reactions with chemicals, such as chlorofluorocarbons, which are released at the surface and transported to the stratosphere. In the troposphere, ozone is a pollutant gas from fossil fuel and biomass burning and from industrial activity. As global air quality degrades, the ability of the atmosphere to cleanse itself chemically is reduced. This in turn could enhance the greenhouse effect by increasing the accumulation of greenhouse gases.

Monitoring ozone depletion in the stratosphere and increase in the troposphere are key requirements of a Global Change Research Program. Measurements of global ozone concentrations as a function of altitude are required along with measurements of the global distribution of the atmospheric chemicals, dynamic processes, and solar energy input that control ozone concentrations. Global-scale models that couple chemistry and dynamics must be used to put the observations into a coherent picture of the atmosphere that allows confident projections of ozone depletion and greenhouse gas buildup for realistic emission scenarios.

UARS will provide focused data on stratospheric chemistry and dynamics in the early 1990s. The Total Ozone Mapping Spectrometer (TOMS), flown as an Earth Probe, will provide data on total ozone to the mid- to late-1990s. After that time, instruments on EOS and NOAA satellites will continue to watch stratospheric ozone depletion and to provide direct global-scale measurements of ozone and greenhouse gases.

EOS includes with its payloads the instruments necessary to study the global processes which control the stratospheric ozone layer and to monitor changes in tropospheric gases. The 15-year life of EOS will allow measurement over a sufficiently large number of annual cycles, biennial oscillations, and ozone changes, to greatly improve our understanding of the ozone layer. It will have the capability to monitor the long- and intermediate-lived chemical components of the troposphere and their long-term changes. The EOS instruments will thus address the central problems of the relation of climate to changing atmospheric chemistry.

26

This time series of stratospheric ozone for the month of October begins in 1980 (far left) and ends in 1989 (the large image). The data, collected by the Nimbus-7 LIMS sensor, show the evolution of the "ozone hole" near Antarctica (increasing from purple-blue to grey).

What is the Role Of The Solid Earth?

Geological and geophysical processes vitally affect life on Earth. The spectacular hazards of volcanic eruption, earthquakes, floods, and landslides are familiar to all who follow the world news. Volcanoes introduce chemicals and aerosols into the atmosphere. Crustal movement results in earthquakes, regional sea-level variations, and potential flood hazards. Changes in the massive amounts of ice now stored in glaciers and polar ice caps could lead to significant changes in sea level and oceanic circulation. Desertification and erosion of large tracts of land affect the global hydrologic cycle and Earth's productivity. The motion of material deep in the core and mantle causes subtle changes in Earth's rotation and length-of-day in ways that are not yet well understood.

Understanding these processes requires a diversity of observations. We need to monitor the gaseous effusion and thermal productivity of volcanoes to gauge atmospheric effects and to assess the likelihood of eruption and potential of resultant hazards. EOS atmospheric and land-surface sensors will be used to characterize the composition and nature of volcanoes. Altimeters and positioning systems will be used to detect expansion of probable hazardous volcanoes.

We need to monitor the mechanisms of plate motion over long periods and during short, drastic events. Densely spaced, high resolution geodetic measurement on a frequent basis is the most likely technique to achieve timely earthquake prediction. High resolution geodetic observation and altimetry are also the keys to understanding regional uplift, subsidence, and associated hazards in coastal areas, as well as change in the shape and volume of polar ice caps. Changes in the Earth's rotation and length-of-day are best monitored using high resolution geodetic techniques, while the deep-seated processes in the Earth which cause these changes are best understood by study of the Earth's magnetic field. We must be able to detect areas of current or potential desertification and erosion, which requires large-scale observation and detailed characterization, and the ability to continually update the observations.

EOS will provide the sensors required to document and understand the interactions between geological and geophysical processes and other components of the Earth system. The diversity of simultaneous observations which will be possible from the EOS platforms will allow timely responses to situations which would not have been possible with earlier techniques. The remote sensing aspects minimize risk of human life in documenting extreme events.

28

Mineralogical and thermal features in the vicinity of Mt. St. Helens based on data from Landsat Thematic Mapper in July 1984, four years after its last eruption; note the "hot spot" in the crater, as well as on the flank of the volcano. The black and white image (315 km square) from Seasat's synthetic aperture radar in 1978 shows surface features in Southern California, including the area where the San Andreas and Garlock Fault Zones converge.

Gathering Comprehensive Global Observations

A new start is proposed for EOS in NASA's FY 1991 budget submission to Congress, with development to be initiated in October 1990. NASA began conceptual studies for EOS in 1982; coordination with the European Space Agency (ESA), Japan, and Canada was initiated in 1986. Present plans call for two series of polar-orbiting platforms: EOS-A and EOS-B. The 15-year observational period will be achieved using three identical satellites per series, each with a five-year design lifetime.

ESA is planning two series of polar platforms with a climatological and terrestrial focus, respectively, and Japan is planning one polar platform. Both NASA and NOAA sensors are planned for inclusion on these platforms. Additionally, NASA is planning to provide sensors as attached payloads for the Space Station.

A group of 41 sensors from the U.S., Canada, Japan, and Europe has been selected as candidates for flight on EOS. The EOS-A series is tentatively planned to focus on atmospheric sounding and surface imaging; selection of specific sensors will be in October 1990. The EOS-B series is planned to include sensors capable of extending observations made by the UARS and TOPEX/Poseidon missions; sensor selection for EOS-B will occur one year later.

Platform size for EOS has been chosen to accommodate atmospheric sounding and surface imaging sensors, a grouping which maximizes the synergistic use of coincident observations, as well as minimizes atmospheric induced uncertainties. The satellites will be launched into polar orbit from Vandenberg Air Force Base on Titan-IV rockets.

An EOS platform will accommodate a payload up to 3500 kilograms and can supply up to 3.2 kilowatts of power to the payload. This platform is twice the size of UARS and can supply about four times the power; it will accommodate two to four instruments more than the 10 aboard UARS. Because of the wider spectral range of the instruments, its data system will manage more than 10,000 times the data of UARS.

The need for global coverage every one to three days dictates a sun-synchronous orbit with a quasi-two-day repeat; a 705-kilometer altitude, 98.2-degree inclination orbit meets this need. It will have a 1:30 p.m. local equatorial-crossing time.

The Synthetic Aperture Radar (SAR), not able to be efficiently accommodated on the EOS series of platforms, is planned for flight on a dedicated satellite in 1999. Its orbit will have a 620-kilometer altitude and similar equatorial-crossing time; this will provide frequent opportunities for coincident observation of the same locations as sensors on EOS platforms.

30

NASA's Mission to Planet Earth includes the EOS-A and -B series of polar platforms, a separate EOS SAR mission, and the TDRS communication link; not shown are the Space Station attached payloads and Earth Probes; related foreign polar platforms include the ESA M-1 and N-1 series, as well as the Japanese JPOP. The smaller image shows a comparison of launch-configuration sizes with EOS-A at a 14.8-meter height.

C-3

Providing Easy Access To Data

The EOS Program has put a major emphasis on the Data and Information System (EOSDIS). EOSDIS is planned to acquire a comprehensive, global, 15-year data set; to maximize the utility of this data set for scientific purposes; and to facilitate its easy access by the research community. In addition to data processing, archival, and distribution facilities, EOSDIS includes the necessary capabilities for command and control of the spacecraft.

The development of EOSDIS will be initiated immediately by building on the existing infrastructure within the research community. It will implement an architecture which is open and distributed, so that it can evolve with advances in computing and networking technology. The near-term objectives are to support the research and analysis of data which both exist and will come from the near-term pre-EOS missions. In this way, the research community can gain valuable early experience in preparation for the future large EOS data volume.

Archived data sets, in addition to those from the EOS satellites, will include complementary *in situ* and satellite data. EOSDIS will also involve the U.S. Geological Survey, National Oceanic and Atmospheric Administration, the National Science Foundation and other agencies.

There will be two types of data products: standard and specialized. Standard products will be generated and archived at Active Archive Centers; the target time for the availability of engineering-level products is within 48 hours of collection; the target for derived geophysical products is within 96 hours. Specialized products will be generated by individual investigators and made available to EOSDIS for archiving and distribution, as appropriate.

The EOSDIS policy specifies that all data and derived products be available to all users, with no preference given to EOS investigators. Research users in the U.S. and participating countries will pay only the nominal cost of data reproduction and delivery; they will be required to agree to publish their results and to make available supporting information, including methods for analyzing data. Research users in other countries may propose cooperative projects and associated "in kind" contributions (i.e., provide similar access to appropriate satellite, aircraft, and surface-based data) in exchange for access to EOS data on similar terms. Access to the raw data stream will be provided to operational agencies for forecasting purposes. NASA will provide for the commercial distribution of data on a non-discriminatory basis to all other users.

32

The distribution of the U.S. EOS investigators, shown along with proposed sites under consideration as EOSDIS Active Archive Centers (Goddard Space Flight Center, Jet Propulsion Laboratory, Langley Research Center, National Snow and Ice Data Center, National Center for Atmospheric Research, University of Alaska, University of Wisconsin, and Michigan Consortium for International Earth Science Information Network).

SUMMARY

Predicting Global Change

Our planet is experiencing profound environmental changes; the economic and social consequences of global change have received attention at the highest governmental levels. To document, understand, and predict global change is a major scientific challenge; but up to now we have lacked the ability to provide the necessary comprehensive information for key policy decisions. Modern technology and new insights offer hope for early warning of change and accurate predictions of future change, and thus major societal benefits.

Mission to Planet Earth, building on precursor research missions and encompassing the proposed Earth Probes and the Earth Observing System, is a major NASA contribution to the U.S. Global Change Research Program. It will provide the necessary comprehensive global observations of Earth which will reveal how the processes that govern global change interact as part of the Earth System. This understanding is critical to the development of models for predicting future environmental change. With a continuing, comprehensive data set from EOS, it will be possible to update and enhance the models so that they can provide the information needed about environmental change on local, regional, and global scales.

Our nation must take the lead in providing sustained observations of the Earth. We have the scientific and technical capability; our national aspirations and spirit demand that we rise to this challenge.

The total cost of EOS is estimated to be 17 billion dollars through the year 2000. The cost of EOS platforms and payloads is commensurate with other large observing programs, such as the four Great Observatories of NASA's Astrophysics Program.

Typically with flight programs, NASA has allocated about 70 percent of the funding for spacecraft hardware and 30 percent for ground-based activities. For EOS, in recognition of the large data volume and the need for a comprehensive science program, NASA will allocate 40 percent for spacecraft hardware and 60 percent for ground-based activities, including EOSDIS and science.

Although the cost of such an observing and data system is large, it is small compared to that of taking no action or acting on incomplete information. Considering the consequences of global change for humankind, we cannot afford to do less. Mission to Planet Earth will enable us to observe, understand, and predict change on Planet Earth.

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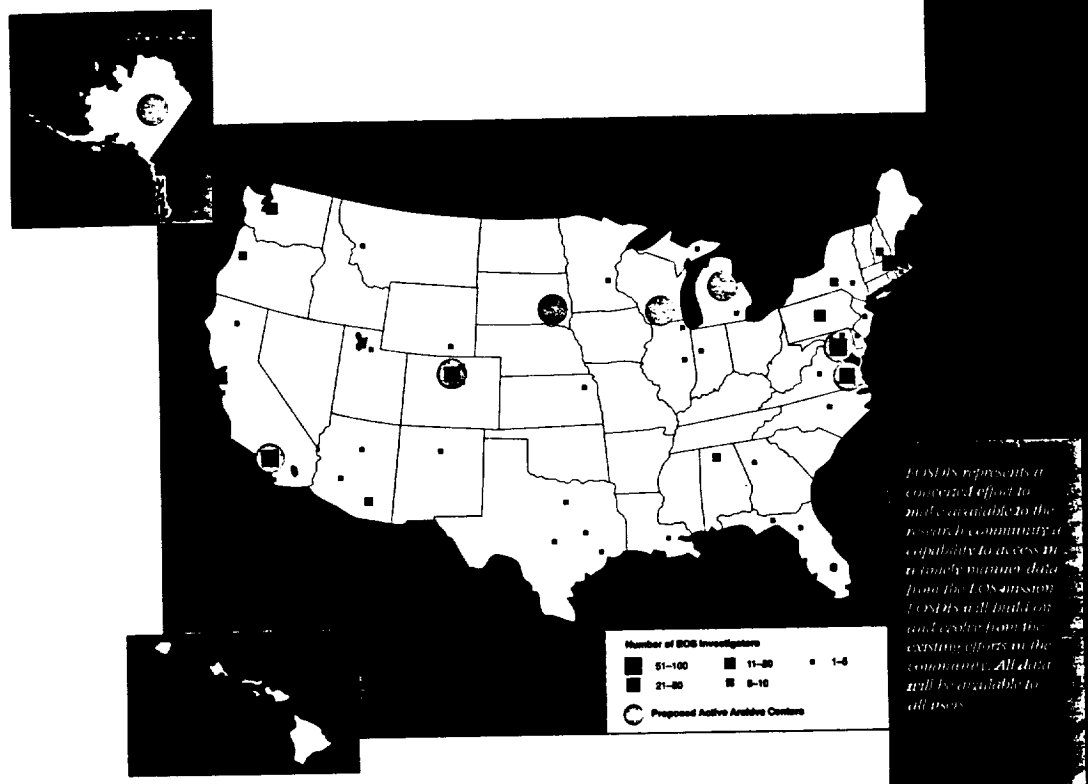
34

This table shows the distribution of the proposed Earth Probes, EOS, and related foreign missions. Near-term activities include the initiation of the EOS science and Data and Information System activities.



33

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NASA's Office of Commercial Programs:
Providing a Focus for Action

Space has become an economic frontier, a new territory of commercial competition, where the spacefaring nations of the world seek new opportunities for industrial growth and economic benefit.

In 1984, the United States Congress amended the 1958 Space Act to assign the National Aeronautics and Space Administration an important new mission: ". . . seek and encourage, to the maximum extent possible, the fullest commercial use of space."

President Bush, in his first presidential address to a joint session of Congress, sounded strong support for this national goal when he called for "more commercial development of space."

NASA's Office of Commercial Programs is providing a focus for action to stimulate and assist an expanded involvement and investment by the U.S. private sector in civil space activities.

Strengthened by a rich tradition of NASA cooperation with industry, the office supports new high-technology commercial space ventures, the commercial application of existing aeronautics and space technology, and greater access by commercial firms to available NASA capabilities and services.

This report, prepared by the Public Affairs Office of the Office of Commercial Programs, highlights NASA-sponsored and assisted commercial space activities of the past year.

For additional information, write to:

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NASA Headquarters
Washington, DC 20546

Contents:

Letter
1989: Establishing a Strategic Vision
The U.S. Private Sector in Space
- Industrial R&D in Space
- Centers for the Commercial Development of Space
- New Cooperative Agreements

Building U.S. Competitiveness Through Technology
- Technology Utilization — A National Priority
- An Exploration of Benefits
- Honoring Apollo-Era Spinoffs

Small Business Innovation
Selected Economic Indicators
- International and Domestic R&D Trends
- Space Sector

Budget Highlights and Trends
Commercial Programs Management
Commercial Programs Advisory Committee

To our shareholders:

James T. Rose

As we observe the 20th anniversary of America's first lunar landing this year, it is important to recognize that our nation's space enterprise has paid "dividends" to every citizen.

Those benefits have come in the form of technological advances, improvements in the quality of our lives here on Earth, and in far-reaching positive impacts on our national economy.

Through cooperative efforts with U.S. industry to commercially develop space and accelerate the commercial application of space technologies, NASA seeks to expand the economic returns from our public investment.

During 1989, we made significant progress in defining an overall program of commercial space development. We have categorized and scoped the different types of commercial space activities, assessed the unique requirements and issues affecting the growth of each, and developed mechanisms to carry out a comprehensive and aggressive program.

We witnessed this year the re-emergence of an active flight program of industrial research and development experiments in space. These industry investigations into the practical commercial uses of space represent a growing interest by the U.S. private sector, stimulated and encouraged by NASA- sponsored programs.

There is an increasing recognition, both in the U.S. and abroad, that space has attributes that are of great value. These resources and characteristics will play a major role in opening a new economic frontier for the spacefaring nations of the world.

It is clear then that commercial development is both a logical next step in America's civil space efforts and a prudent competitive strategy.

Our challenge is to organize these efforts into a program that develops commercial space markets, low-cost commercial space transportation systems, and a commercial space infrastructure industry.

The rewards of our success will be significant contributions to America's future industrial competitiveness, and the maximum economic returns to our stockholders — the American people.

JAMES T. ROSE
NASA Assistant Administrator for Commercial Programs

Amid a dramatic growth of activity and interest in the commercial development of space, NASA's Office of Commercial Programs (OCP) focused in 1989 on the establishment of a strategic vision.

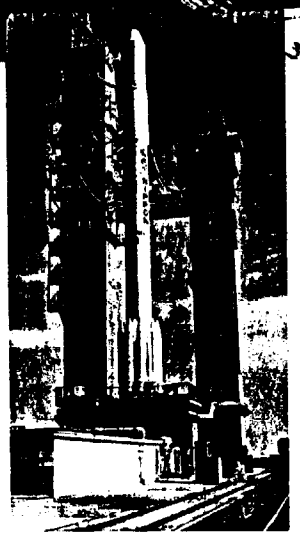
Several key initiatives carried out during the year will culminate in a strategic plan, founded in national space policy goals for expanding U.S. space commercial activity.

The need for a strategic vision, and a plan for realizing its goals, is clear.

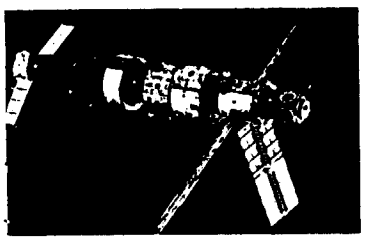
Space harbors valuable resources that represent a new economic frontier for the spacefaring nations of the world. The commercial development of space is both a logical next step and a prudent competitive strategy.

In Europe and Japan, our increasingly space-capable trading partners have identified the attributes of Earth orbit as having significant potential for producing new high-technology products and services with global markets. Foreign firms operate with a high level of direct and indirect government support, enhancing their competitive position.

Above: Space Shuttle orbiter, outfitted with the European-built *Spacelab* orbital laboratory, enables the exploration of the unique attributes of space. Right: West German payload specialist conducts experiments aboard *Spacelab* in the U.S. Space Shuttle during a mission purchased by the Federal Republic of Germany.



Japanese development of the H-1 rocket is indicative of increasing capability and interest in the industrial uses of space.



Glavkosmos, the Soviet Union's commercial space marketing organization, is offering opportunities for use of the *Mir* space station.

Other space powers, notably the Soviet Union and China, have become aggressive marketers of space transportation and related services, seeking to attract foreign currency into their economies.

Between 1984 and 1988, President Reagan and the U.S. Congress, recognizing the importance of a policy framework that would foster American leadership in the economic development of space, took the first major steps to focus federal action on an expanded role for the U.S. private sector in the nation's civil space program.

These actions included an amendment to the 1958 Space Act that directed NASA to "seek and encourage, to the maximum extent feasible" the commercial use of space, and the incorporation of commercial space initiatives into the administration's national space policy.

Early in his term, President Bush signaled a continued emphasis on the economic importance of space commercial development.

Based on major efforts this year to identify key issues, define appropriate relationships between government and industry, and chart a course toward U.S. preeminence in space commerce, the Office of Commercial Programs' strategic planning has three key goals:

- Actively fostering the development of space-related markets.
- Improving the availability of and access to transportation and infrastructure to support emerging markets and new ventures.
- Using NASA resources to support the development and growth of successful commercial space ventures.

"We must have a manned space station, a vigorous, safe Space Shuttle program, and more commercial development of space."

— President Bush addressing Joint Session of Congress

Seeking U.S. Space Industrial Competitiveness

The Commercial Programs Advisory Committee (CPAC), a distinguished panel of industry chief executive officers and their university counterparts, serving as a standing committee of the NASA Advisory Council, issued this year its first formal recommendations, embodied in a report entitled *Charting the Course: U.S. Space Enterprise and Space Industrial Competitiveness.*

The CPAC was established in 1988 through the initiative of NASA Assistant Administrator for Commercial Programs James T. Rose. Chaired by Edward Donley, Chairman, Executive Committee, Air Products and Chemicals, Inc., the CPAC undertook a thorough review of commercial space issues, and formulated a series of key recommendations for consideration by the nation's leaders.

These recommendations, most addressing critical policy issues, and the continuing input from the CPAC, are helping to shape the commercial development strategic plan.

Also supporting the OCP's strategic planning effort was a study conducted this year by the American Institute of Aeronautics and Astronautics (AIAA) to lay groundwork for the strategic plan by defining issues and potential objectives associated with the commercial development of space.

The AIAA formed a steering committee consisting of senior-level private sector managers. The resulting study document, *Issues in Strategic Planning for Commercial Space Growth,* represents inputs from more than 90 industry representatives.

The AIAA study addresses overall goals and objectives, the scope of commercial space activities, and the roles of industry, academia, and government. It also explores issues and barriers, and suggests federal actions and policy changes.

New Analysis Capabilities and Policy Guidelines

OCP's Plans, Policy, and Evaluation Division, which coordinated and supported the 1989 strategic planning activities, also established this year a financial and business analysis function and managed the development of commercial space infrastructure policy guidelines.

With the continuing growth of the commercial space sector, and increasing competition for limited resources, the new financial and business analysis capability provides information to help NASA decision-makers in their review of candidate commercial ventures.

Commercial space infrastructure guidelines issued this year are intended to provide a framework to encourage U.S. commercial investment and involvement in NASA's space and technology programs.

Commercial space infrastructure is that portion of space infrastructure — the facilities, services, and systems that enable space activities — in which the private sector retains a permanent interest and responsibility.

The OCP also established procedures and criteria to guide NASA's orderly, timely, and equitable evaluation of commercially initiated proposals for infrastructure systems or services.

Industrial R&D in Space

A resurgence of industrial research and development activity in space took place this year following the successful return of the Space Shuttle to flight operations in September 1988.

The flight of STS-26 included the involvement of several U.S. pharmaceutical companies in an investigation of protein crystal growth and a 3M experiment in organic thin films.

In 1989, the Office of Commercial Programs sponsored commercial development payloads on two more Space Shuttle flights and funded the first U.S. commercial launch of a materials science payload.

The Commercial Development Division focused on supporting the growth of industry payloads stemming from increased demand for flight opportunities.

The division has projected a total of 12 commercial payload flights through FY 1990 for launch aboard the Space Shuttle and commercial sounding rockets. Four of these payloads are manifested through March 1990. Another 22 payloads are projected for flight opportunities in the 1991 timeframe.

Most of this commercial interest is directed towards focused or applied research in the behavior and processing of materials in the microgravity environment of space. The industry demand also reflects commercial interest in privately developed space infrastructure and support services and in commercial Earth observations.

In an effort to match space transportation and support capabilities with the anticipated growth in industry requirements, the Commercial Development Division in 1989 initiated grant funding for a commercial sounding rocket program.

The division also identified the need for the commercially provided *Spacehab* module as a carrier for NASA-sponsored industry payloads and discussions were initiated for NASA's use of *Spacehab*, scheduled to make its first flight in 1992.

The 1989 spaceflight activity sponsored by the Office of Commercial Programs consisted of:

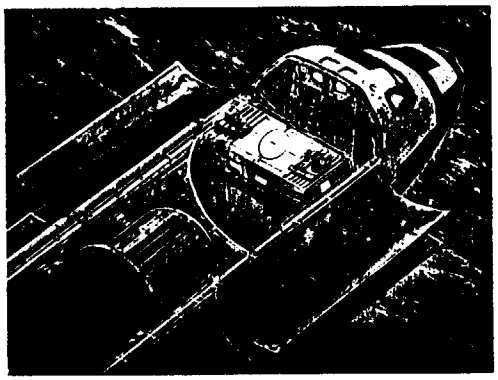
1) Another flight of protein crystal growth experiments aboard the Space Shuttle *Discovery* in March. These experiments, coupled with those performed on STS-26, produced clear evidence that microgravity enables the manufacture of superior crystals.

Protein crystals made in space may help to significantly advance medical research into new treatments for cancer, rheumatoid arthritis, high blood pressure, AIDS, and other diseases.

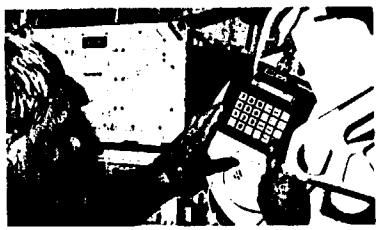
The experiments were conducted by scientists at the Center for Macromolecular Crystallography, a NASA Center for Commercial Development of Space (CCDS) at the University of Alabama–Birmingham, in collaboration with industrial researchers representing eight leading U.S. pharmaceutical companies.

2) An experiment in the space processing of indium conducted aboard the Shuttle *Atlantis* in April. This research was performed in Rockwell International's Fluid Experiments Apparatus (FEA) flown under a Joint Endeavor Agreement with NASA. Collaborating with Rockwell in the investigation was the Indium Corporation of America, exploring through microgravity research the prospects of obtaining higher purity indium.

3) The March 29 launch of materials processing experiments developed by the Consortium for Materials Development in Space, a NASA CCDS at the University of Alabama–Huntsville, aboard Space Services, Inc.'s, Starfire rocket at White Sands Missile Range, New Mexico. The suborbital flight, which provided seven minutes of microgravity, represented the first federally licensed commercial launch.



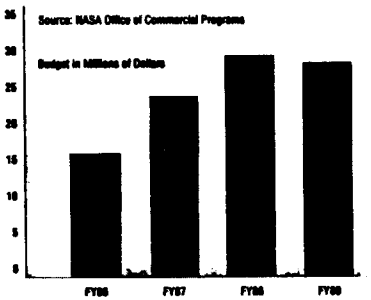
Left: SPACEHAB, Inc., is constructing pressurized research modules to fly in the Shuttle cargo bay. These modules will provide expanded opportunities for commercial users. The firm will lease volume to experimenters and pay NASA for launch costs under a Space Systems Development Agreement (SSDA). SPACEHAB's first flight is manifested for early 1992.



Right: Astronaut George "Pinky" Nelson operates 3M's experiment in organic thin films on mission STS-26. Flying for the second time under 3M's Joint Endeavor Agreement with NASA, the industrial research equipment produced thin film samples during a 1985 Shuttle mission. 3M has obtained a patent on a new material discovered in the investigation.

Liftoff of Space Service Inc.'s Starfire rocket on March 29 marked the first federally licensed commercial launch. After a brief suborbital flight providing about seven minutes of microgravity, the payload of materials science experiments was recovered.

OCP Budget for the Commercial Use of Space
(Current Dollars)



Protein crystals grown aboard the Space Shuttle have helped investigators determine that better-formed crystals can be grown in microgravity, as demonstrated by the photos of space-grown (top), and ground-grown crystals. Improved protein crystals may prove to be of great benefit to medical researchers seeking to develop new drug treatments for cancer, high blood pressure, emphysema, and other diseases.

In collaboration with its industry partners, the Consortium for Materials Development prepared six experiments to investigate the manufacture of new materials in space.

4) Preparations for the flight of 3M's experiment on the effects of microgravity on polymeric materials, scheduled for flight on STS-34 in October. The flight will be 3M's fifth, and will be the first under a 10-year Joint Endeavor Agreement calling for up to 62 flight experiment opportunities.

In addition to the flight activity, industrial research and development was supported in 1989 through continued programs enabling access to NASA ground and airborne facilities for microgravity and remote sensing investigations.

These activities included cooperative agreements with U.S. firms for use of NASA drop towers at the Lewis Research Center in Cleveland, Ohio, and the Marshall Space Flight Center in Huntsville, Alabama; NASA microgravity and remote sensing research aircraft; the Earth Resources Laboratory at Stennis Space Center, near Bay St. Louis, Mississippi; and life sciences capabilities at Ames Research Center, Moffett Field, California.

CCDS Summary - 1989

CCDS	COMMERCIAL FOCUS	AFFILIATES		
		INDUSTRY	UNIVERSITY	GOVERNMENT
MATERIALS PROCESSING IN SPACE				
BATELLE	Electronics, Polymer, and Catalysis Applications—Aeropropulsion, Airframes and Space Structures	6	7	1
UAH	Superconductors and Electro-optical Materials—Optical Scanners, Satellite Components...	9	0	1
VANDERBILT	Metals, Alloys, Ceramics, and Glasses—Solar Dynamics, Nuclear Systems, Turbines, Nozzle Components...	7	2	3
CLARKSON	Electronics, Communications—Computers, Semiconductors...	11	4	6
HOUSTON	Thin Film Growth and Materials Purification—Electronics, Magnetic Devices, Computer Circuits...	7	0	3
SPACE STRUCTURES				
CASE WESTERN	Films, Expandable Structures—Space Structures...	9	1	2
REMOTE SENSING				
ITD SRSC	Processed Remote Sensing Information—Forestry, Fisheries, Agriculture...	12	0	5
OHIO STATE	Remote Sensing Sensor and Display Applications—Coastal Planning, Crop Stress, Mining...	9	0	3
LIFE SCIENCES				
PENN STATE	Understanding of Cell Functions for Disease Treatment—Osteoporosis, Growth System...	14	0	3
COLORADO BIOSERVE	Pharmaceutical, Health Care, or Agricultural Production	30	4	2
UAB	Crystal Growth for Use in New Pharmaceuticals or Biotechnology	11	10	4
ROBOTICS				
WISCONSIN	Automation and Robotics—Dexterous Robot Hands, Intelligent, Flexible Automated Systems...	12	3	2
ERIM	Sensor and Automated Manipulation Technology for Hazardous Environments—Nuclear Waste Clean Up, Mining...	9	1	3
SPACE POWER				
AUBURN	Alternative Commercial Space Power—Transmission Systems, Advanced Controllers...	4	4	6
TEXAS A&M	Commercial Space Power Systems—Microwave Transmission, Space Station Augmentation...	24	3	7
SPACE PROPULSION				
TENNESSEE	Alternative Space Propulsion Technologies	8	3	2
	TOTAL	160	50	50

Centers for the Commercial Development of Space

NASA's network of sixteen Centers for the Commercial Development of Space witnessed continued progress towards attracting significant involvement by U.S. firms in space commercial development.

The number of corporate affiliations with the CCDS centers grew to 180, and the share of financial contributions by industry members continued to increase. For the first five CCDSs, established by the Office of Commercial Programs in 1985, the ratio of private-to-government support is now approximately 3:1.

NASA initiated the CCDS program to attract a broad U.S. industry involvement. The centers represent consortia of university, industry, and government involved in early research and testing stages of potentially viable products or services.

A CCDS Management Operations Working Group was established last year by OCP and the group functioned effectively in 1989, serving as a coordinating body for collaborative efforts and program planning.

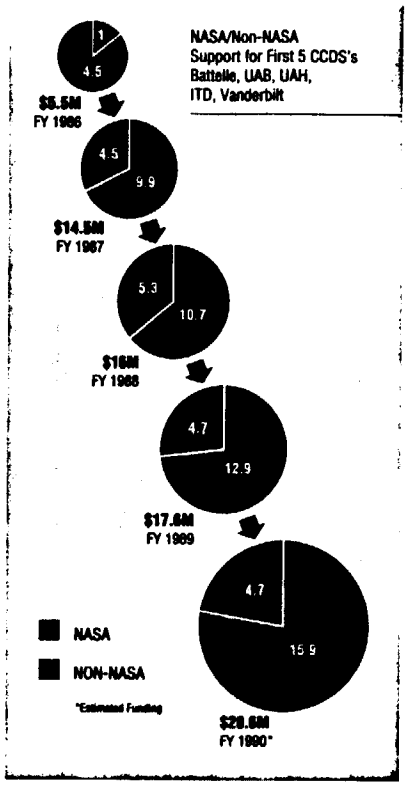
Among the most significant CCDS achievements of 1989 were:

- Spaceflight experiments coordinated and conducted by the Center for Macromolecular Crystallography (University of Alabama–Birmingham) and the Consortium for Materials Development in Space (University of Alabama–Huntsville).
- The development of a stronger, more efficient power supply through a collaborative effort by the Center for Commercial Development of Space Power (Auburn University) and Maxwell Laboratories, San Diego, California.

While conducting research into space power equipment, the research team identified potential commercial applications to existing terrestrial markets. The advance, already being marketed by Maxwell, represents the first technology spinoff by a NASA CCDS.

- The initiation by the Space Vacuum Epitaxy Center (University of Houston) of a hardware development project to build a wake shield facility to enable commercial research in a high ultra-pure vacuum during Space Shuttle flights.

Centers for the Commercial Development of Space (CCDS) Funding Leverages (Dollars in Millions)



Satellite pictures of Earth, like this false-color image of a frontier basin in Asia, help Unocal scientists identify deposits of oil and gas. Unocal is working with NASA to advance its use of remote sensing technology.

Right: Artist concept of the wake shield facility deployed on the end of the remote manipulator arm.

Above: A Space Shuttle external tank, photographed after it was jettisoned during the flight of STS-29. The University Corporation for Atmospheric Research (UCAR) plans to use up to five ETs for conducting experiments during their suborbital flight.

New Cooperative Agreements

NASA in 1989 expanded its partnership with U.S. industry through the signing of cooperative agreements providing support for industrial space research, commercial space transportation, and the private development of space infrastructure and services.

Commercial launch vehicle agreements were signed with Martin Marietta, enabling the firm to gain access to payload processing facilities at the Kennedy Space Center; LTV Missile and Electronics Group, granting the firm exclusive rights to commercially produce and market the Scout launch vehicle; and with Conatec, of Lanham, Maryland, facilitating the firm's use of NASA launch facilities at Wallops Island, Virginia.

A Memorandum of Agreement (MOA) was signed with the University Corporation for Atmospheric Research (UCAR), Boulder, Colorado, establishing the terms and conditions for use of the Space Shuttle's external tanks for suborbital experiments. Completed in December 1988, the agreement will make available to UCAR the use of up to five designated external tanks.

A Memorandum of Understanding (MOU) signed with the Coca-Cola Company will support the firm's investigation of fluid dynamics, gas-liquid separation, and metering technologies in space.

NASA also signed a Memorandum of Understanding (MOU) with Corabi International Telemetrics, Inc., a Maryland-based telemedicine systems company, supporting the commercial development of telemedicine services for the Space Station *Freedom*.

In addition to these signed agreements, a number of candidate Joint Endeavor Agreements and Space System Development Agreements were identified during 1989.

Among the companies discussing potential cooperative agreements with NASA is Unocal (Union Oil of California), already engaged in a commercial remote sensing project under a Proprietary Work Agreement with Stennis Space Center.

Genentech, a biotechnology firm which is working in collaboration with the Center for Cell Research (Pennsylvania State University) and signed this year a Technical Exchange Agreement with NASA's Ames Research Center, is also discussing other potential cooperation.

Biocryst, a Birmingham, Alabama, firm, is seeking to commercialize technologies being developed by the Center for Macromolecular Crystallography.

NASA uses a number of innovative and functional agreements that provide industry with assistance, services, and facilities to help reduce the risks associated with commercial space ventures.

Joint Endeavor Agreements (JEA) involve no exchange of funds and are designed to encourage private companies to conduct space research and development leading to new products and services. Private industry funds the experiments and NASA provides transportation and other services.

Space Systems Development Agreements (SSDA) provide industry with a deferred payment schedule for Space Shuttle launch services. This allows a new commercial space venture to have a more favorable cash flow during a time when capital investment costs are typically the greatest.

Technical Exchange Agreements (TEA) are designed for companies interested in commercial applications but not yet ready to commit to specific spaceflight experiments or ventures. Under this agreement, NASA and a company agree to exchange technical information and cooperate in the conduct and analysis of ground-based research programs.

Other agreements, such as Memoranda of Understanding and Memoranda of Agreement, provide a framework for meeting other commercial interests in cooperation with NASA.

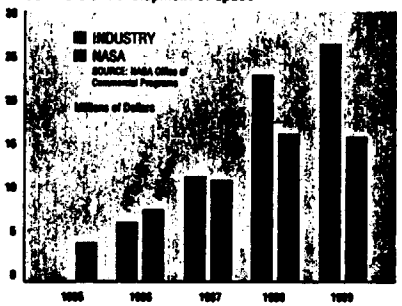
Commercial Space Involvement of Fifty Largest U.S. Industrial Corporations

		Agreements	CCSD Affiliations
1	GENERAL MOTORS		1
2	FORD MOTOR		
3	EXXON		
4	INTERNATIONAL BUSINESS MACHINES		1
5	GENERAL ELECTRIC		1
6	MOBIL		
7	CHRYSLER		
8	TEXACO		
9	E.I. DU PONT DE NEMOURS		3
10	PHILIP MORRIS		
11	CHEVRON		
12	AMOCO		1
13	SHELL OIL		
14	OCCIDENTAL PETROLEUM		
15	PROCTER & GAMBLE		1
16	UNITED TECHNOLOGIES	TEA	8
17	ATLANTIC RICHFIELD		
18	EASTMAN KODAK*		1
19	BOEING	JEA, OTHER	5
20	E.I.R MARASCO		
21	DOW CHEMICAL		1
22	XEROX		
23	USX		
24	TENNECO		
25	MCDONNELL DOUGLAS	MOU	4
26	PEPSICO		
27	WESTINGHOUSE ELECTRIC		3
28	ROCKWELL INTERNATIONAL	JEA, CPAC	6
29	ALLIED-SIGNAL		
30	DIGITAL EQUIPMENT		1
31	PHILLIPS PETROLEUM		1
32	GOODYEAR TIRE & RUBBER		1
33	LOCKHEED		3
34	MINNESOTA MINING & MANUFACTURING	JEA,CPAC*	6
35	CATERPILLAR		
36	SARA LEE		
37	WEYERHAEUSER		
38	UNISYS		
39	HEWLETT-PACKARD		
40	ALUMINUM CO. OF AMERICA		
41	GENERAL DYNAMICS	MOU	1
42	INTERNATIONAL PAPER		1
43	GEORGIA PACIFIC		
44	COMAGRA		
45	JOHNSON & JOHNSON		
46	ANHEUSER-BUSCH		
47	UNOCAL	CPAC	8
48	SUN		
49	COCA-COLA	MOU	8
50	UNION CARBIDE		

KEY
* CPAC Member retired from Corporation
JEA: Joint Endeavor Agreement
MOU: Memorandum of Understanding
CPAC: Commercial Programs Advisory Committee
CCSD: Center for the Commercial Development of Space
TEA: Technical Exchange Agreement
MOA: Memorandum of Agreement

Source: Fortune, "The Fortune 500", April 24, 1989 and NASA Office of Commercial Programs

NASA and Industry Support for the Centers for the Commercial Development of Space



In 1989, NASA's Technology Utilization Division continued to open new avenues for the transfer of NASA-developed technologies to the public and private sectors.

By participating in a number of new cooperative ventures and implementing new initiatives, NASA's nationwide technology transfer network has been further strengthened and expanded.

In addition, the division has taken an active role in national efforts aimed at helping to regain America's industrial competitive strength by increasing federal technology transfer activities and improving coordination among the government agencies involved.

As a proactive force in technology utilization for more than 26 years, NASA's Technology Utilization Division has helped to promote and facilitate the transfer of literally thousands of NASA spinoffs.

These spinoffs, in areas as diverse as medicine and transportation, have generated a multitude of social and economic benefits for the entire nation to reap.

Technology Utilization — A National Priority

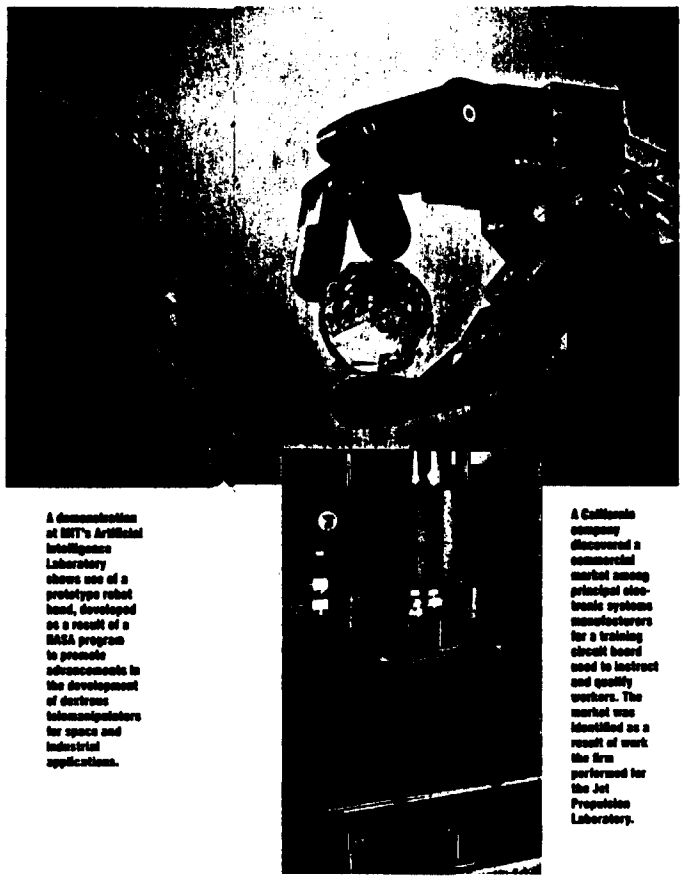
Shortly after his inauguration, President Bush urged Americans to "take actions today that will ensure a better tomorrow. We must extend American leadership in technology, increase long-term investment, improve our educational system, and boost productivity. These are the keys to building a better future."

The President's comments not only echoed the concerns of a nation, but also form the basis of recent legislative and executive directives concerning technology transfer.

The failure of many U.S. firms to capitalize on the research and technologies generated in federal programs is widely viewed as a major factor in the U.S.'s declining global marketplace position.

In an effort to bridge this critical gap, NASA has continued to review and strengthen its own technology utilization program, comply quickly with specific directives, and work closely with other organizations.

In 1989, the agency began implementation of a new strategic plan, which serves as a guideline for NASA technology tranfers. The plan was formulated following a thorough review of the program in 1988.



A demonstration at MIT's Artificial Intelligence Laboratory shows use of a prototype robot hand, developed as a result of a NASA program to promote advancements in the development of dextrous telemanipulators for space and industrial applications.

A California company discovered a commercial market among principal electronic systems manufacturers for a training circuit board used to instruct and qualify workers. The market was identified as a result of work the firm performed for the Jet Propulsion Laboratory.

NASA was also the first federal agency to distribute its patent royalty income as required by Public Law 99-502. On June 3, 1988, checks totaling $56,944 were issued to 35 current and former NASA employee-inventors.

The checks paid the inventor's share of NASA's patent royalty income received between the effective date of the Federal Technology Transfer Act of 1986 (October 20, 1986) and December 31, 1987. Some $61,000 in royalties received during 1988 are currently being distributed.

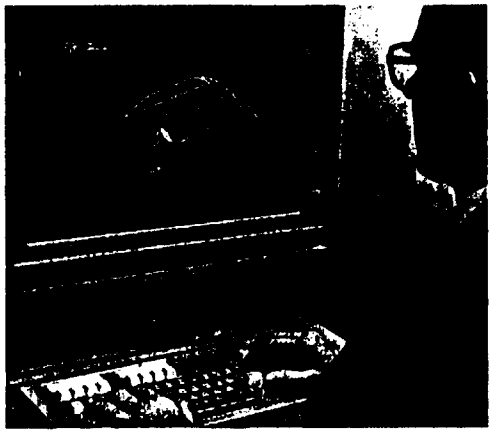
In addition, NASA responded to a mandate from congressional conferees of the Committees on Appropriations aimed at coordinating federal technology transfer efforts by providing industry with a single point of contact.

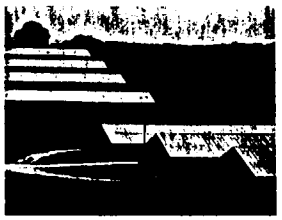
The mandate directed NASA's Office of Commercial Programs to "conduct a definition/design study of the five-year master plan for the establishment of a national repository for federal research and development (technology tranafer), which would be located in West Virginia. . . ." Five-year cost estimates and a proposal for cost sharing were also requested.

NASA assigned preparation of the study to the Technology Utilization Division, which in turn formed a task team of technology transfer experts to assist with the effort.

Following the development of a preliminary National Technology Transfer Center design, the task team solicited comments from representative federal agencies involved in the technology transfer process.

The incorporation of these inputs helped produce a plan that promises significant benefits for the public and private sectors. The plan was submitted to the Committees on Appropriations in the House of Representatives and Senate on February 1, 1989.





Advanced computer software developed by NASA and available through NASA's Computer Software Management and Information Center (COSMIC), has been used widely by U.S. industry. Structural design and analysis software has, for example, been employed by Chrysler Corp. in automobile engineering, and by the University of Georgia Agricultural Engineering Department, seeking to improve poultry facilities for the benefit of Georgia's billion-dollar-a-year poultry industry.

Another initiative underway involves transferring what NASA has learned about space-related science, engineering, and technology to our nation's school systems.

Under the proposed effort, the feasibility of producing a high-school textbook or textbooks is being investigated. The textbook could be offered to the public sector for licensing and publishing and subsequently be available for use in high schools across the country.

It is hoped that the availability of such a textbook would facilitate a dramatic increase in the number of high-school space science classes offered, sparking the interest and imaginations of America's students and encouraging them to pursue science and engineering studies at the university level.

An Expanded TU Network

New links to public and private-sector groups in 1989 have helped to enhance both the size and scope of NASA's nationwide technology transfer network, as well as to fulfill national economic objectives.

With the addition of seven new affiliates, the network now extends into 40 states across the country.

Through a variety of mechanisms, the network allows NASA to move information into the private sector and to assist in its application.

A recent agreement with the Center for New West (CNW) will link the NASA network to CNW members and affiliates in eighteen western states.

CNW is a nonprofit policy research organization committed to understanding America's emerging new economy, promoting economic growth in the western U.S., and improving the competitiveness of western enterprise in the world marketplace.

A Memorandum of Understaning (MOU), signed by NASA and CNW, will provide a vehicle for the exchange of information, dissemination of research results, and development of joint projects.

Major agreements between NASA field centers and five states are expected to enhance NASA's technology transfer efforts, as well as impact favorably on the economic activities of each state.

The MOUs, signed by NASA and the states of Alabama, West Virginia, Tennessee, Virginia, and Florida, were negotiated by NASA Field Center Technology Utilization Officers and are expected to lead to new joint endeavors.

In addition, a cooperative venture between NASA and the state of California is expected to help advance research in the highly dynamic research area of superconductivity.

Recognizing that superconductivity technologies promise to play an important role in the future of California industry and NASA missions, the two parties are cosponsoring a pilot Superconductivity Applications Center. The project will consist of a technical program and center related activities.

Under the technical program, which will be sponsored primarily by the state of California, NASA's Jet Propulsion Laboratory and the California Institute of Technology will work on four superconductivity-related research tasks in cooperation with TRW and Rockwell International.

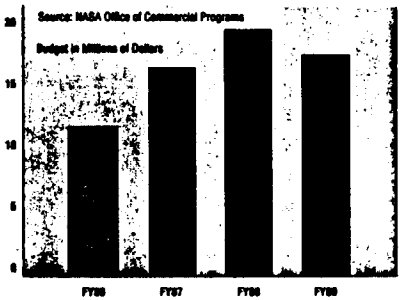
Center related activities will be sponsored by NASA and will include program management, program analyses and integration, and center design and development.

The Technology Utilization Division is also working closely with the Department of the Navy to assist in development of a Navy Technology Transfer Center.

The Navy is interested in identifying state-of-the-art technology available in industry, academia, and other government agencies, and in bringing it into Navy repair and maintenance facilities to solve critical problems.

Under the initiative, NASA's Industrial Applications Centers (IACs) will work on a number of Navy projects, evaluating problems, assessing potential solutions, and recommending courses of action. The Navy has transferred initial funding for the effort to NASA and is currently prioritizing projects and holding discussions with various IACs.

OCP Budget for Technology Utilization
(Current Dollars)



NASA's AdaNet program is currently in Phase II of its implementation plan. The AdaNet Software Repository is intended to be a self-supporting commercial organization to provide users of Ada with information sharing and depository services.

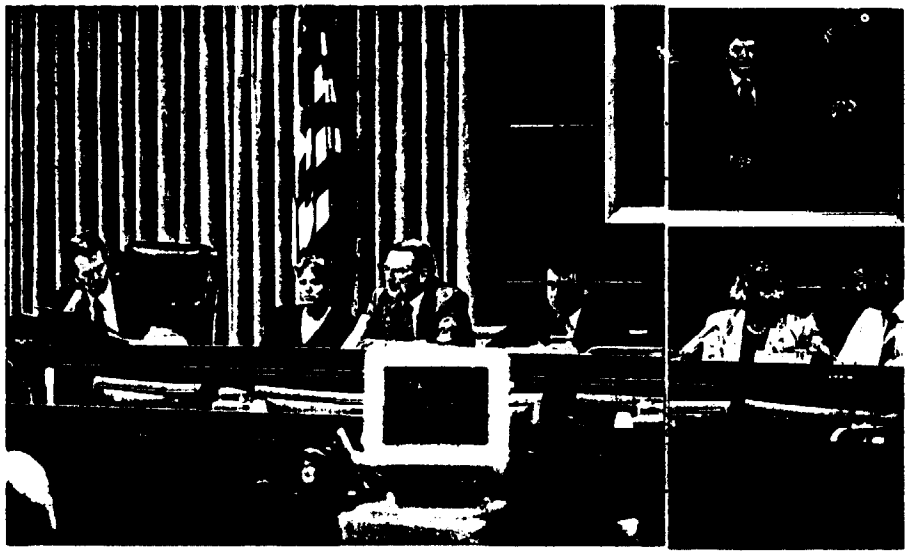
It will operate on a for-profit basis and is targeted to become self-sustaining through client income by 1991.

NASA is also planning to enhance the capabilities of field center technology utilization offices through implementation of a microcomputer-based system that efficiently stores data and facilitates timely access to new technologies developed in NASA programs.

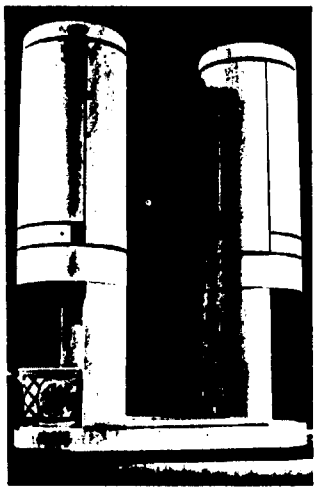
This system will complete the linkage of NASA technology utilization field installation offices, COSMIC, the NASA Scientific and Technical Information Facility, and IACs to provide a quicker distribution of new technologies than had been previously possible.

Application Efforts

NASA's direct support of technology application efforts in 1989 helped to produce advances in fields ranging from medicine to transportation. Some 80 application projects are currently being conducted at nine NASA field installations.



House Subcommittee on Space Science and Applications conducts hearing on the technology spinoffs from the space program.



NASA Tech Briefs magazine reaches more than 100,000 subscribers annually. Elna, Inc., a California firm, discovered a NASA-patented device designed by an astronaut to produce brewed coffee in space. Obtaining a license to commercialize the device, Elna has developed and is now marketing this new coffee maker.

At an April hearing of the House Subcommittee for Space, Science, and Applications, numerous commercial applications of NASA-developed technologies were described by company and university officials representing a diverse array of fields.

The witnesses recounted a number of "success stories" in which NASA application projects had resulted in social and economic gain.

One of the projects described at the hearing was the Sterling engine. The Sterling is an external combustion engine that, when compared with conventional internal combustion engines, offers a number of unique advantages. It is a high-torque engine that operates at a constant speed. It uses one spark plug, needs no muffler, emits no noxious gas, and can use fuel of any kind.

In addition to use in vans and trucks, the engine is also being considered for irrigation pumping and mobile processing in agriculture, drying process in the lumber industry, and for use on trawlers, dredges, and shrimp boats in the fishing industry.

A multi-year, multi-phase demonstration program has been created by an industry/government team to obtain early operation and performance data; evaluate integrity, reliability, and durability; and accelerate development.

Given its many advantages and versatility, the Sterling engine may have profound impacts on both the transportation and processing industries.

A major advance in diabetes control has resulted from another application project.

Known as the Rechargeable Physiologic Sensor, an implantable device is being developed that promises to free one million Type 1 insulin dependent diabetics, in the U.S. alone, from numerous daily finger-prick blood tests required to monitor glucose levels.

The device will also provide a more accurate analysis of glucose levels. Researchers expect a prototype sensor to be completed by the end of 1989 and predict that a commercial unit could be in the marketplace within four years.

Application projects are geared toward the solution of public and private sector problems that have been identified by user organizations. Direct NASA assistance and primary funding are provided.

They involve cooperative efforts to build and test prototype hardware if the industrial partner agrees to provide partial funding and is prepared to complete marketing of the transfer.

Two application teams, Research Triangle Institute and Rural Enterprises, Inc., are presently operating. The teams broker industrial clients' needs and match such needs with NASA technology. In FY 1990, NASA will continue to broaden application team responsibilities.

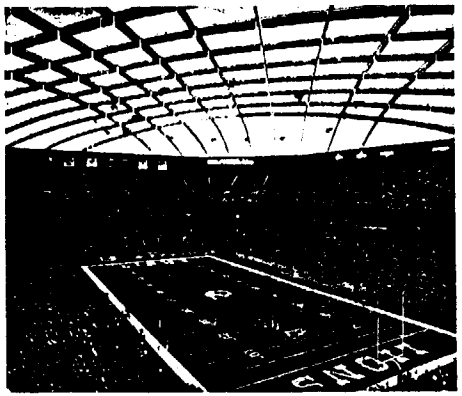
Increasing Visibility

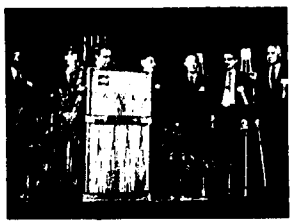
NASA's technology transfer efforts have received increased media attention, with articles on the subject appearing in national publications and numerous radio and television broadcasts focusing on NASA spinoffs.

The 20th anniversary of Apollo 11 this year resulted in an extraordinary level of interest in the spinoffs associated with America's effort to land the first men on the Moon.

In addition, the scope and circulation of *NASA Tech Briefs* and *Spinoff* publications continues to grow. *Tech Briefs*, which identifies new technologies developed in NASA programs, is presently receiving 1,500 inquiries per day for more detailed information on specific technologies.

Likewise, NASA's annual *Spinoff* continues to report new applications of NASA-developed technologies.





Special fabric developed in the 1960s for spacesuits provided the basis for material used later in construction-grade fabrics. The first adaptation of this technology was in Michigan's Silverdome. NASA technology utilization managers and the team of individuals credited with the application of space technology to use in fabric structures are recognized at this year's Spinoff Hall of Fame ceremony in Colorado Springs, Colorado.

Twenty years ago: Man on the Moon.

An Exploration of Benefits

A contracted study to assess the economic impacts of NASA technology transfer was completed this summer, resulting in new findings that indicate substantial financial benefits to U.S. business.

Entitled An Exploration of Benefits From NASA *"Spinoff,"* the study was conducted by the Chapman Research Group, Inc., of Littleton, Colorado.

The research determined the estimated revenues and cost-savings derived from a sample of applications reported in NASA's *Spinoff* publication.

More then 400 applications reported in the magazine between 1978 and 1986 were traced. It was found that 342 applications resulted in acknowledged contributions to sales or savings. Of these, about 75 percent, or 259 cases, permited some quantification of sales or savings. The 259 applications were determined to have contributed to the sales of new or improved products in the amount of $21.3 billion and contributed to savings of nearly $316 million.

It was also calculated that the revenues produced through the estimated sales generated federal income tax revenues of nearly $356 million. Additionally, 352,000 jobs were projected to have been created, or retained due to the increased revenues (not savings) attributed to these spinoffs.

This study continues to identify the enormous social and economic benefits generated by NASA's technology transfer efforts.

Because it concentrates on a few applications and measures only some of the quantitative benefits derived from those applications, the study may reveal only a fraction of the real value stemming from the "spinoff" of NASA technology.

Honoring Apollo-Era Spinoffs

This year marked the 20th anniversary of the U.S. space program's greatest triumph: the first human footsteps on the Moon.

At special events in Washington, D.C., and Paris, the astronaut crew of Apollo 11 recalled the historic flight, and shared with national leaders and citizens of the world a perspective on that achievement of July 20, 1969.

In May, the U.S. Space Foundation honored three technology spinoffs that resulted directly from the program to land Americans on the Moon.

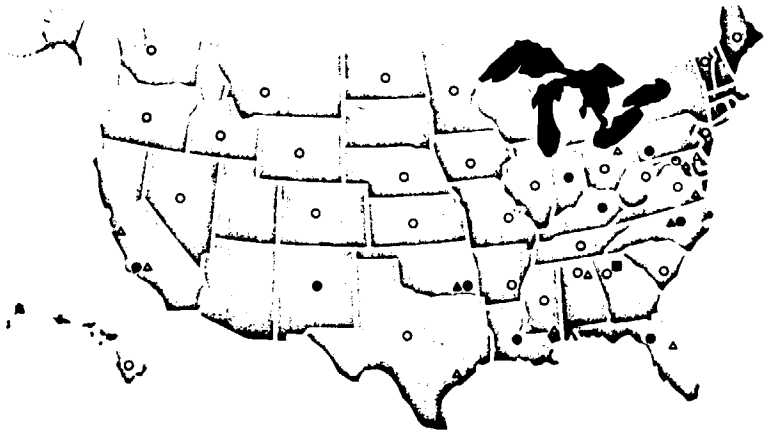
The organization hosted a special ceremony in Colorado Springs, Colorado, its headquarters, to recognize the individuals and organizations instrumental in the adaptation of Apollo technology for use in:

- Cordless Tools, developed by Black and Decker as a derivative of specialized tools used by the Apollo astronauts to collect lunar samples.
- Scratch Resistant Lenses, which use the technology developed for protecting the reflective visors on the astronaut's helmet.
- Fabric Structures, like the covering over the Silverdome football stadium in Pontiac, Michigan. The fabric used in such construction is a derivative of the Apollo spacesuit material.

These three technologies, inducted into the U.S. Space Foundation's Spinoff Hall of Fame, represent but a few of the thousands of technology applications to be spun off from the Apollo program.

The national commitment to land U.S. astronauts on the Moon and return them safely to Earth spurred major advances in emerging technologies, such as computers, which became smaller, lighter, and more efficient, to meet the requirements for manned spacecraft. Today, twenty years after Apollo 11's "giant leap for mankind," the technology that enabled that achievement continues to enhance our lives on Earth through uses in fields such as health, safety, recreation, manufacturing, transportation, and energy.

NASA's Technology Transfer System



△ **Field Center Technology Utilization Officers:** manage center participants in regional technology utilization activities.

● **Industrial Applications Centers:** provide information retrieval services and assistance in applying technical information relevant to user needs.

○ **Industrial Applications Centers Affiliates:** state-sponsored business or technical assistance centers that provide access to NASA's technology transfer network.

■ **The Computer Software Management and Information Center (COSMIC):** offers government-developed computer programs adaptable to secondary use.

▲ **Application Team:** works with public agencies and private institutions in applying aerospace technology to solution of public problems.

During 1989 the NASA Small Business Innovation Research Program (SBIR) received a substantial increase in funding. This, along with wider understanding of the opportunities offered by SBIR, resulted in a large increase in small, high-technology business participation in the program.

NASA's SBIR program, now entering its seventh year, implements the Small Business Innovation Development Act of 1982. The legislation requires government agencies with research and development (R&D) budgets exceeding $100 million to set aside 1.25 percent of their annual R&D appropriations for the award of Phase I and Phase II SBIR contracts. Eligibility requirements for small businesses and program implementation guidelines for all participating agencies are provided by the Small Business Administration.

SBIR program objectives established by law include stimulating technological innovation in the private sector, strengthening the role of small businesses in federal R&D programs, fostering and encouraging greater participation of minority and disadvantaged persons in technological innovation, and increasing private sector commercialization of innovations derived from federal R&D.

A recent survey conducted by NASA of completed SBIR projects indicated that all these objectives are being achieved and that the program has become a highly regarded element of NASA's overall R&D activities. An assessment of the SBIR program conducted by the General Accounting Office concurred with NASA's findings.

The NASA survey found that the results of more than half the SBIR projects reviewed have already been incorporated or will soon be incorporated into NASA mission programs and that many projects have substantially advanced the technology base in several areas. The survey revealed that the quality of research conducted in SBIR projects was as high or higher than comparable research funded through other R&D means, and that at least one-fourth of the projects had already resulted in commercial products or enterprises by the small businesses.

NASA data also indicate that a substantial number of minority and disadvantaged firms have won SBIR contracts for high-technology projects.

Benefits Realized From NASA-Furnished Technology Case Applications From *Spinoff*
(Reports By Categories of End Use Sales or Savings, Thousands of Dollars*)

END USE DESCRIPTION	NUMBER OF CASES	NUMBER OF CASES WITH SALES OR SAVINGS	BENEFITS SALES	REALIZED SAVINGS	$(000) TOTAL
Communication/Data Processing	61	32	171,697	51,994	222,571
Energy	30	13	202,800	16,813	219,113
Industrial (mfg & process)	170	107	5,787,549	67,857	5,855,406
Medical	81	31	2,000,000	30,513	2,030,549
Consumer Products	34	16	1,270,394	534	1,270,918
Public Safety	27	16	347,000	000	349,443
Transportation	40	18	9,897,000	116,023	10,004,400
Environmental	16	11	16,002	21,700	38,760
Other	22	13	1,004,000	16,232	1,005,221
Total	441	200	$21,221,100	$316,740	$21,040,000

*Estimates were obtained from company officials, or derived from company estimates of manpower or other types of savings (see Appendix A, Study Approach and Conduct). The 441 cases were reported in *Spinoff* magazine, 1976-88; of these 300 had acknowledged sales or savings, but 100 cases could not be estimated as to extent.

NASA SBIR Program Award Statistics

PROGRAM SOLICITATION YEAR	PHASE I PROPOSALS	PHASE I AWARDS	PHASE I TOTAL FUNDING $M	PHASE II PROPOSALS	PHASE II AWARDS	PHASE II TOTAL FUNDING $M	PHASE I & II TOTAL PROGRAM FUNDING $M
1983	977	102	5.0	92	50	24.0	29.0
1984	919	127	6.3	113	71	32.5	38.8
1985	1164	150	7.4	129	84	39.3	46.7
1986	1628	172	8.5	154	85	39.2	47.7
1987	1825	204	10.0	178	100	47.9	57.9
1988	2379	228	11.3	NA	NA	NA	NA
TOTALS TO DATE	9000	983	48.6	957	380	182.9	280.1(1) 231.4(2)

NOTE: (1) Total Program Funding Shown is for First Five Program Solicitation Years
(2) Total Program Funding Shown is for First Five Program Solicitation Years, Plus 1988 Phase I

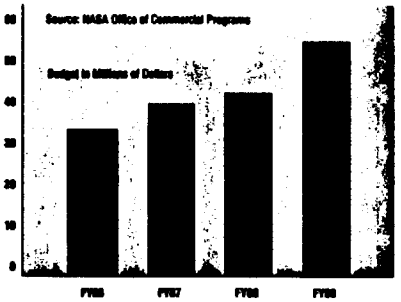
Program Elements

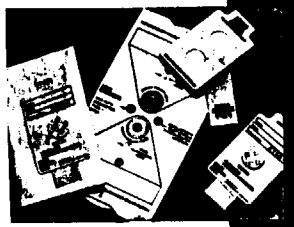
The SBIR program consists of three distinct phases. Phase I objectives are to establish the feasibility of innovative concepts proposed by small businesses to meet NASA program objectives, solve problems, or exploit new technological opportunities. Phase I projects are completed in six months and are funded up to $50,000.

Phase II is the principal SBIR activity, in which more than half of the Phase I projects are more fully developed. Phase II projects may be funded up to $500,000 and may take up to two years to complete.

In Phase III, the small firm uses private sector capital to commercialize its SBIR project result, to sell its product or service to a government agency or contractor, or to obtain government support for further R&D. Phase III may not employ SBIR set-aside funding.

OCP Budget for Small Business Innovation Research
(Current Dollars)





GMD Systems of Hendersonville, Pennsylvania, under contract to NASA's Kennedy Space Center, developed a badge for monitoring workers' exposure to the toxic propellant hydrazine.

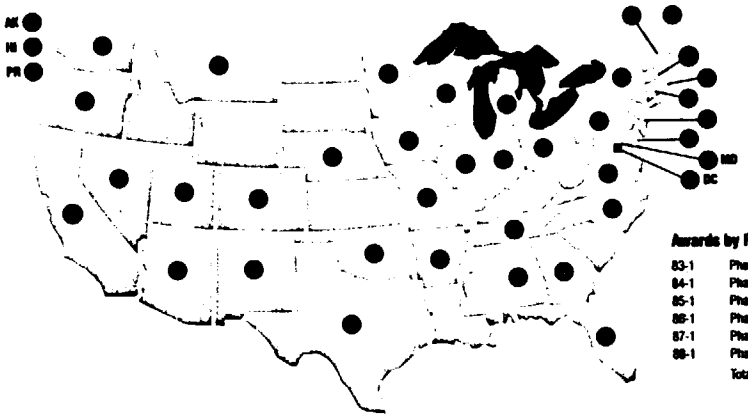
Through an SBIR contract with NASA's Johnson Space Center, Houston, BoMed Medical Manufacturing Ltd., an Irvine, California, firm, developed a non-invasive heart monitor that has been incorporated into a commercially successful system.

FY 1989 SBIR Activities

SBIR activities during FY 1989 included the selection of 228 Phase I awards from the nearly 2,400 proposals submitted in response to the 1988 Program Solicitation. During 1989, 100 Phase II awards were made for further development of Phase I projects initiated during 1988. The 1989 SBIR program was initiated with the issuance of the 1989 SBIR solicitation. Other activities included program outreach and efforts to foster commercialization of SBIR results.

NASA's 1989 SBIR Program Solicitation invited Phase I proposals in fifteen areas of technology subdivided into 150 specific subtopics. Nearly 25,000 copies of the solicitation were distributed, and by its closing on June 28, more than 2,140 Phase I proposals had been received. Those found responsive to the solicitation were distributed to the nine NASA field centers for technical evaluation. It is planned that at least 225 Phase I awards will be announced in early FY 1990.

SBIR outreach activities in 1989 included participation in more than a dozen conferences and seminars aimed at assisting small businesses in understanding the NASA SBIR program. In an effort to anticipate and encourage winning companies to develop the commercial potential of SBIR results, the SBIR Office has initiated a program to follow and report on projects as they proceed. Other efforts have centered on strengthening ties with NASA's network of Industrial Application Centers and Centers for the Commercial Development of Space to foster technology transfer and commercial application of technology developed under NASA R&D programs.



Awards by Program Year

83-1	Phase I & II	(160)
84-1	Phase I & II	(199)
85-1	Phase I & II	(234)
86-1	Phase I & II	(256)
87-1	Phase I & II	(304)
88-1	Phase I	(228)
	Total	1381

SBIR Projects

Two projects that began in 1985 illustrate the impact and value of SBIR projects both to NASA and to the nation.

BoMed Medical Manufacturing Ltd. of Irvine, California, received a contract through Johnson Space Center to develop a continuous, non-invasive means to monitor bloodflow through the heart and thereby assess the heart's condition. The company delivered a successful device now being used in research on the effects of weightlessness on astronauts.

The company sold a version of this monitor for use in hospital operating rooms and intensive care units and invested in the development of a comprehensive system for non-invasive hemodynamic and cardiodynamic patient monitoring and therapeutic management. In 1988 it launched its new system. Revenues have increased seven-fold since 1984, and the company is now profitable. BoMed attributes much of its success in this field to the opportunity provided by SBIR.

GMD Systems, Inc., of Hendersonville, Pennsylvania, has been working with the Kennedy Space Center to develop a badge that will measure a worker's exposure to hydrazine. Hydrazine is an extremely toxic fuel with various applications, including use in the Space Shuttle's Orbital Maneuvering Vehicle.

The badge monitors a worker's cumulative exposure by changing color and responds to the current permissible exposure limit for hydrazine in as little as 15 minutes. This will allow employees to evacuate a contaminated work zone before hydrazine has accumulated to dangerous levels.

Because this is the first hydrazine detector to measure personal exposure levels, the firm expects there to be a significant market wherever it is used, whether in spacecraft, missiles, boiler cleaning, or fertilizer production.

Future Focus

Based on the FY 1990 budget request, the NASA SBIR budget is expected to exceed $60 million, from which NASA anticipates considerable growth in the numbers of SBIR contracts awarded and of small businesses participating in NASA's R&D programs.

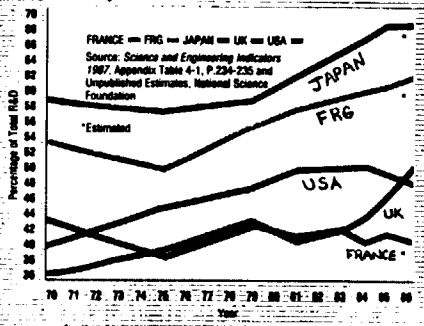
Efforts to promote commercial development of SBIR project results will continue to focus on disseminating project results more widely and developing linkages between the SBIR program and the NASA Industrial Application Network, the Small Business Development Centers, and the Centers for the Commercial Development of Space.

International and Domestic R&D Trends

The charts and graphs included in this section characterize key international and domestic trends in research and development expenditures. International comparisons focus on spending by major U.S. trading partners who are also active in space research and commercial applications.

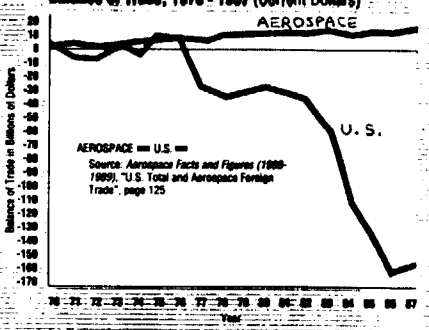
Space sector data demonstrate the commercial space interests of leading U.S. industrial corporations, the contribution of the high-technology aerospace industry to the U.S. balance of trade, and information on the emerging commercial launch vehicle industry and its competitive position.

Percentage of Total R&D Expenditures Funded by Business



Space Sector

Aerospace Balance of Trade Versus Overall U.S. Balance of Trade, 1970 - 1987 (Current Dollars)

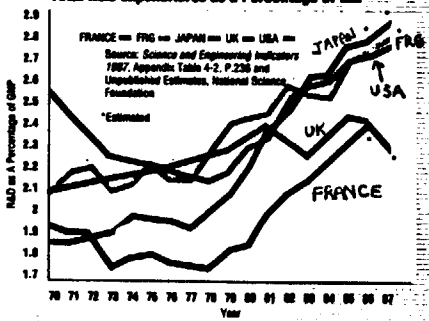

AEROSPACE
U.S.
AEROSPACE — U.S.
Source: Aerospace Facts and Figures (1988-1989), "U.S. Total and Aerospace Foreign Trade", page 125
Balance of Trade in Billions of Dollars
Year

Government Civil Space Applications Budgets (Approximate)

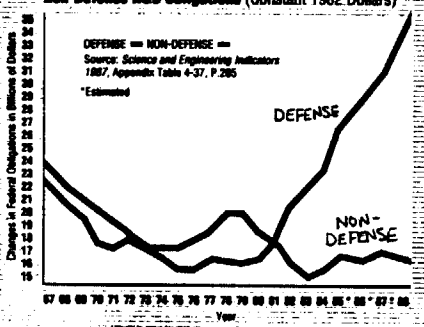
Entity	Satellite Communications		Remote Sensing		Materials Processing	
	1983/84	1987	1983/84	1987	1983/84	1987
ESA	222	249	41	196	75	39
FRANCE	53	105	92	120	8	14
WEST GERMANY	100	30	5	8	22	32
JAPAN	73	109	66	99	9	14
CANADA	33	36	35	43	N/A	N/A
TOTAL	480	529	239	466	114	99
U.S.A.	32	100	15	24	22	35

SOURCE: *U.S. Civil Space Program: An AIAA Assessment*, March 1987, AIAA

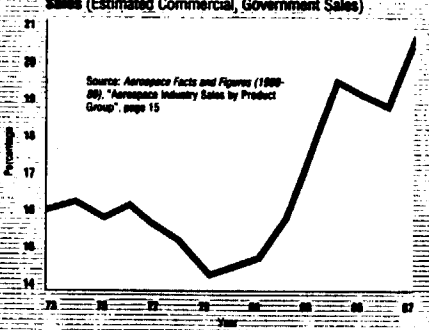
Total R&D Expenditures as a Percentage of GNP



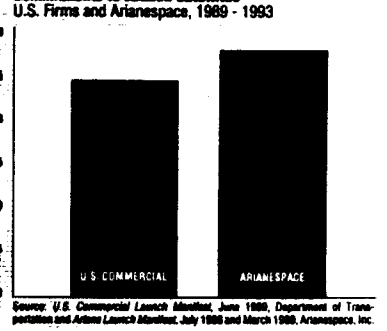
Relative Changes in Federal Defense and Non-Defense R&D Obligations (Constant 1982 Dollars)



Space Product Sales as a Percentage of Aerospace Sales (Estimated Commercial, Government Sales)

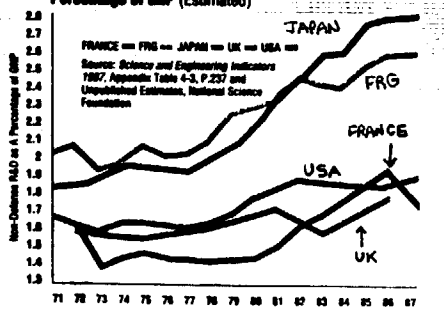


Commitments to Launch Satellites
U.S. Firms and Arianespace, 1989 - 1993

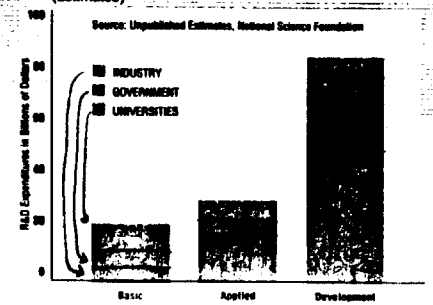


Source: *U.S. Commercial Launch Manifest*, June 1988, Department of Transportation and *Ariane Launch Manifest*, July 1988 and March 1988, Arianespace, Inc.

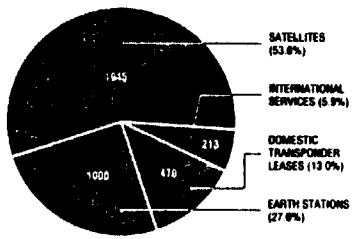
Non-Defense R&D Expenditures as a Percentage of GNP (Estimated)


FRANCE — FRG — JAPAN — UK — USA
Source: Science and Engineering Indicators 1987, Appendix Table 4-3, P.237 and Unpublished Estimates, National Science Foundation
JAPAN
FRG
FRANCE
USA
UK
Non-Defense R&D as A Percentage of GNP

U.S. Basic and Applied R&D by Sector, 1988 (Estimated)



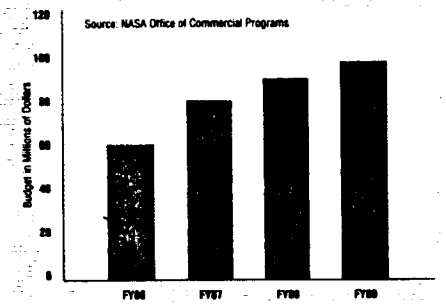
Communications Satellite Revenues (Estimated, Millions of Dollars, by Market, 1986)



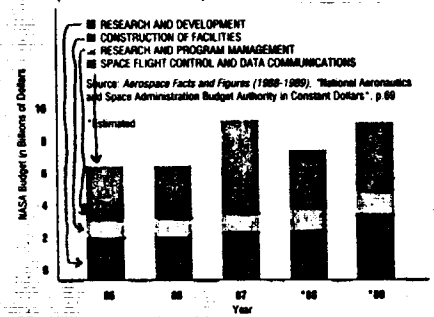
Source: Space Market Model, Space Business Information Center, August 1988

Presented in this section are the budget history of the Office of Commercial Programs, a review of the overall NASA budget trend, and economic impacts attributed to NASA funding.

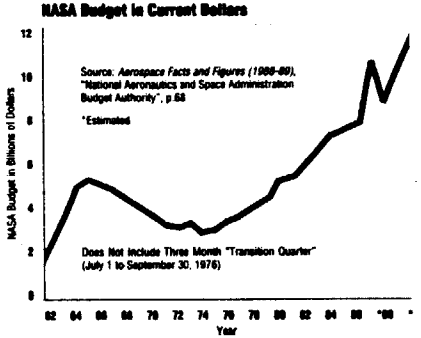
OCP Budget History (Current Dollars)



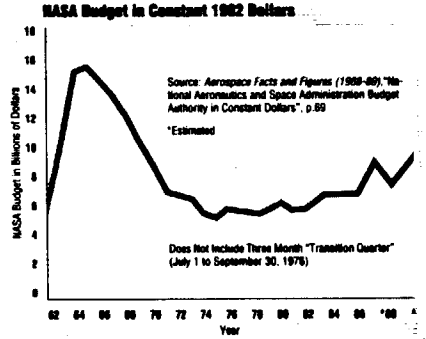
NASA Budget Breakdown by Function
(Constant 1982 Dollars)


RESEARCH AND DEVELOPMENT
CONSTRUCTION OF FACILITIES
RESEARCH AND PROGRAM MANAGEMENT
SPACE FLIGHT CONTROL AND DATA COMMUNICATIONS
Source: Aerospace Facts and Figures (1988-1989), "National Aeronautics and Space Administration Budget Authority in Constant Dollars", p.69
*Estimated
NASA Budget in Billions of Dollars
Year

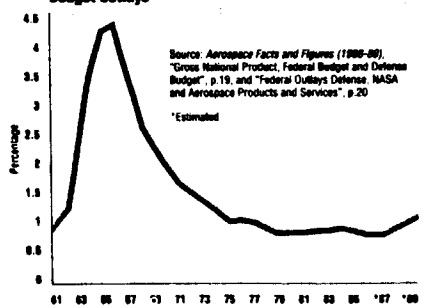
NASA Budget in Current Dollars


Source: Aerospace Facts and Figures (1988-89), "National Aeronautics and Space Administration Budget Authority", p.68
*Estimated
Does Not Include Three Month "Transition Quarter" (July 1 to September 30, 1976)
NASA Budget in Billions of Dollars
Year

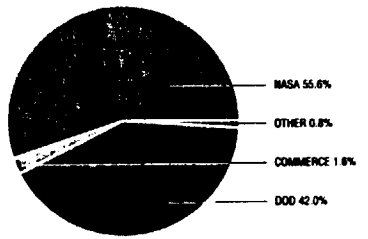
NASA Budget in Constant 1982 Dollars


Source: Aerospace Facts and Figures (1988-89), "National Aeronautics and Space Administration Budget Authority in Constant Dollars", p.69
*Estimated
Does Not Include Three Month "Transition Quarter" (July 1 to September 30, 1976)
NASA Budget in Billions of Dollars
Year

NASA Budget Outlays as a Percentage of Federal Budget Outlays

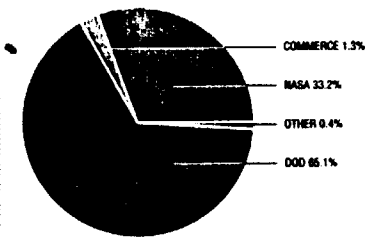

Source: Aerospace Facts and Figures (1988-89), "Gross National Product, Federal Budget and Defense Budget", p.19, and "Federal Outlays Defense, NASA and Aerospace Products and Services", p.20
*Estimated
Percentage

U.S. Space Spending by Department, 1978
(Millions of Current Dollars, Estimated)



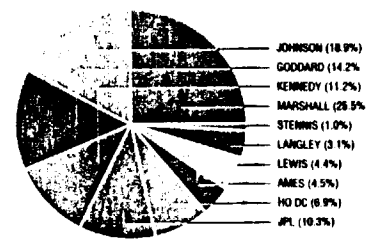
Source: *Aerospace Facts & Figures (1988-1989)*, "Federal Space Activities Budget Authority", p.66

U.S. Space Spending by Department, 1988
(Millions of Current Dollars, Estimated)



Source: *Aerospace Facts & Figures (1988-1989)*, "Federal Space Activities Budget Authority", p.66

NASA Procurement by Center
(Fiscal Year 1988, Estimated)



Source: *NASA Pocket Statistics, January 1988*, "Total Procurement by Installation" p.C-1, "Employment Summary", p.C-26

NASA Procurement and Employment by Center, FY88

	PROCUREMENT ($Millions)	EMPLOYMENT*	
		Federal Employees	Support Contractors
MARSHALL SPACE FLIGHT CENTER	2428	3429	1231
JOHNSON SPACE CENTER	1806	3498	8590
GODDARD SPACE FLIGHT CENTER	1356	3727	3300
KENNEDY SPACE CENTER	1069	2330	9364
NASA RESIDENT OFFICE/JPL	986	5628	
LEWIS RESEARCH CENTER	418	2716	1246
HEADQUARTERS	661	1829	809
AMES RESEARCH CENTER	432	2160	1928
LANGLEY RESEARCH CENTER	297	2986	1720
STENNIS SPACE CENTER	92	159	1213

*As of September 30, 1988

Source: *NASA Pocket Statistics*, January 1988, "Total Procurement by Installation", p.C-4, "Employment Summary", p.C-26

States in Which NASA Procurements Created Over 1000 Jobs (Estimated Direct and Indirect Effects on Employment, FY87)

	Employment (Number of Jobs)
CALIFORNIA	63612
TEXAS	17094
FLORIDA	13462
MARYLAND	10342
ALABAMA	7457
OHIO	7264
NEW YORK	6728
VIRGINIA	5862
CONNECTICUT	5452
UTAH	5330
PENNSYLVANIA	5111
COLORADO	4876
NEW JERSEY	4810
ILLINOIS	4801
LOUISIANA	3929
MICHIGAN	3727
MASSACHUSETTS	3719
MISSOURI	2829
GEORGIA	2743
INDIANA	2695
WASHINGTON	2688
ARIZONA	2111
NORTH CAROLINA	2096
TENNESSEE	1903
MISSISSIPPI	1858
WISCONSIN	1736
MINNESOTA	1550
KANSAS	1383
KENTUCKY	1185
OKLAHOMA	1100
NEW MEXICO	1080

Source: Management Information Services Inc., 1988

States in Which NASA Procurements Generated Over $100 Million in Sales (Estimated Direct and Indirect Economic Effects, FY87)

	Sales ($Millions)
CALIFORNIA	5219.5
TEXAS	1653.8
FLORIDA	996.7
MARYLAND	756.5
OHIO	707.7
ALABAMA	633.9
NEW YORK	543.0
VIRGINIA	481.3
PENNSYLVANIA	460.3
CONNECTICUT	457.4
UTAH	456.9
LOUISIANA	426.4
ILLINOIS	420.5
MICHIGAN	388.9
NEW JERSEY	385.5
COLORADO	379.5
MASSACHUSETTS	290.4
INDIANA	263.1
MISSOURI	260.5
WASHINGTON	235.9
GEORGIA	228.2
MISSISSIPPI	178.7
ARIZONA	176.1
NORTH CAROLINA	174.6
TENNESSEE	158.9
WISCONSIN	149.4
KANSAS	132.6
OKLAHOMA	127.2
MINNESOTA	126.8
KENTUCKY	110.5
NEW MEXICO	108.1

Source: Management Information Services Inc., 1988

States in Which NASA Awarded Over $1 Million in Contracts, FY1988 (Businesses, Educational Institutions, and Non-profits))

	Contract Awards ($Millions)
CALIFORNIA	2411.4
TEXAS	913.1
FLORIDA	873.4
MARYLAND	661.3
ALABAMA	547.8
UTAH	429.2
LOUISIANA	332.2
VIRGINIA	318.3
OHIO	159.6
NEW JERSEY	112.3
PENNSYLVANIA	105.1
COLORADO	86.6
MISSISSIPPI	85.0
CONNECTICUT	76.1
MASSACHUSETTS	64.0
DISTRICT OF COLUMBIA	56.7
NEW YORK	55.0
NEW MEXICO	45.6
WISCONSIN	32.4
TENNESSEE	21.5
ARIZONA	21.1
KANSAS	20.7
MICHIGAN	17.6
WASHINGTON	17.5
GEORGIA	15.7
ILLINOIS	15.2
MISSOURI	13.4
INDIANA	11.7
MINNESOTA	9.0
IOWA	7.9
NEW HAMPSHIRE	7.4
HAWAII	6.9
NORTH CAROLINA	6.2
DELAWARE	3.6
OKLAHOMA	3.4
OREGON	2.9
ALASKA	2.8
RHODE ISLAND	2.5

Source: *NASA Pocket Statistics*, January 1989, "NASA Contract Awards by State", p.C-4

Commercial Programs Management

JAMES T. ROSE *Assistant Administrator*

LAWRENCE F. HERBOLSHEIMER *Deputy Assistant Administrator*

J. MICHAEL SMITH *Deputy Assistant Administrator* (Program Development)

RICHARD H. OTT *Director,* Commercial Development Division

HENRY J. CLARKE *Director,* Technology Utilization Division

HARRY W. JOHNSON *Director,* Small Business Innovation Research Division

DR. BARBARA STONE *Director,* Plans, Policy, and Evaluation Division

THOMAS D. BROWN *Director,* Program Support Division

Commercial Programs Advisory Committee

In July 1988, the Commercial Programs Advisory Committee (CPAC) was formally created to provide NASA with a diverse, high-level industry viewpoint on commercial space business.

As a subcommittee of the NASA Advisory Council, the group was chartered to assist NASA by reviewing policies and programs, and by recommending strategies to implement national space policy goals.

Committee members were drawn from the ranks of U.S. corporate chief executives and their university counterparts.

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EDWARD DONLEY
Chairman, Executive Committee
Air Products and Chemicals, Inc.

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JOE B. WYATT
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Vanderbilt University

B

By Congressional mandate, it is NASA's responsibility to promote expansion of technology transfer in the public interest. The instrument of that purpose is the Technology Utilization Program, through which NASA seeks to encourage greater use of its knowledge bank by providing a link between the technology and those who might be able to put it to advantageous use.

This year marks the 25th anniversary of the Technology Utilization Program. During the quarter century span, NASA's own efforts to apply the technology and those of imaginative entrepreneurs have generated tens of thousands of secondary applications, or "spinoffs."

This publication describes a few of the many. It is a random sampling that illustrates the breadth and diversity of aerospace spinoff and underlines the scope of the benefits that have accrued. Some spinoffs offer only moderate increments of economic gain or lifestyle improvement; many others, however, have economic values running to millions of dollars. Collectively, they represent a substantial return on the national investment in aerospace research in terms of contribution to the U.S. economy, job production, industrial productivity, lifestyle innovations and solutions to problems of public concern.

James T. Rose

Assistant Administrator for Commercial Programs
National Aeronautics and Space Administration

Spinoffs in

Health and Medicine

In aerospace design, every subsystem must be super-efficient and ultrareliable, yet as small and light as technology permits—requirements that are shared by many types of medical devices. That's one reason why the field of health and medicine has been a particular beneficiary of aerospace spinoff.

The United States leads the world in the technology of building complete, reliable aerospace systems in incredibly tiny packages and that technology has spawned a line of life-saving medical adaptations. An outstanding example is the cooperative/development of human-implantable systems by a group of research organizations and medical equipment manufacturers who applied such space technologies as advanced long-life batteries, microminiaturized components, electronic sensors and telemetry, the wireless relay of coded signals for high-volume two-way communication between Earth and orbit. Some examples of the results:

▲ A rechargeable cardiac pacemaker that eliminates the recurring need for surgery to replace batteries.

▲ An advanced heart pacer that may be reprogrammed without surgery—via biotelemetry—as a patient's condition changes.

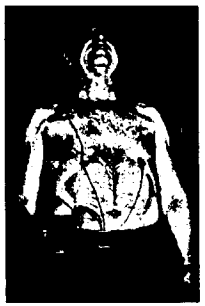
▲ A human tissue stimulator that provides relief from chronic pain by sending electrical impulses to targeted nerve centers.

▲ An automatic implantable "defibrillator" that senses the start of fibrillation—in which the heart loses its ability to pump blood—and corrects it by sending an electrical impulse to the heart.

▲ A programmable implantable system that automatically dispenses precisely-measured medication—such as insulin for diabetics—to target organs.

Described on these pages are a few of thousands of applications of aerospace technology that have provided extraordinary benefit to the field of health and medicine.▲

Wearer of a rechargeable cardiac pacemaker, the child is shown with the companion unit that sends an electrical charge to the pacer's battery without surgery.



A wearable computerized system that allows physicians to monitor ambulatory patients with coronary artery disease incorporates technology originally developed to observe the heart action of Space Shuttle astronauts. It continuously evaluates and records heart signals, alerts to danger and allows physicians to determine the efficacy of treatment.

A patient (seated) is briefed on the operation of a wearable system that continuously delivers insulin—through a needle under the skin—for treatment of diabetes, a life-extending invention derived from space microminiaturization techniques.

Body imaging is the art of creating pictures of human interiors to aid physicians in diagnosis, treatment and surgery. The X-ray is a familiar example. But where the X-ray shows only bone structure, medicine now has available a broad range of body scanning equipment and techniques to penetrate bone and produce highly informative images of body tissue and organs.

Much of this technology stemmed from the space technique known as digital image processing, developed as a means of assembling a picture of a planet or moon from bits of sensor data sent to Earth in digital form by a distant spacecraft. Later advances brought ways to correct sensor errors, change picture contrast, emphasize certain features, make measurements, generally to amplify the information that can be extracted from the computerized image.

This explosively-proliferating new technology has spun off to such varied fields as defense equipment, non-destructive testing, archeology, chemistry, cartography, manufacture of printed circuitry, metallurgy, ultrasonics and seismography. Nowhere has image processing technology been more importantly or more effectively employed than in medicine, where it has enabled advancements in CAT scanning, diagnostic radiography, brain and cardiac angiography, sonar body scanning and monitoring surgery. The illustrations show a representative few of the scores of image processing spinoffs in medicine. ▲

NMR – nuclear magnetic resonance – is a promising new technique for diagnostic body scanning, but NMR imagery is complex and difficult to interpret. Space image enhancement technology offers a means of simplifying interpretation for better diagnosis. Three black and white NMR images were computer-enhanced to create this chest scan "theme map," in which each color represents a different type of tissue and a tumor mass (top center) is precisely outlined.

Now in use in more than 20 states and a number of foreign countries, slow scan TV – a technology that originated in the U.S. space program – makes possible instant consultation between medical centers and specialists at home or in their offices. The specialist views the patient's body imagery inexpensively transmitted over a standard telephone line, allowing accelerated diagnosis that could be vitally important to an emergency patient.

The medical technician is using the system pictured to get a computerized analysis of a microscope specimen that will provide far more information than visual interpretation and do it far more rapidly. This system, several related systems and the whole company that produces them are all spinoffs from NASA digital image processing technology.

For lunar exploration, astronauts needed a compact, lightweight, battery-powered long-use drill to extract core samples from beneath the lunar surface. Under NASA contract a company developed one, then used the technology to produce a line of cordless tools for consumer, industrial and medical use. That's one example of how a space requirement generates new technology for everyday products; here are a few others in the field of health and medicine:

▲ A contractor developed an automatic gas analyzer to monitor Apollo astronauts' respiratory gases; it is now used in hospitals for analysis of anesthetics.

▲ A life-search experiment on a Mars-landing spacecraft required development of miniaturized valving technology, which became the foundation of a family of civil-use fluid control devices, such as a filtering system that removes impurities from blood.

▲ Newborn premature babies are warmed—without noise or burn hazard—in cradles whose electricity-conducting canopies provide controlled radiant heat, an offshoot of NASA technology developed for heated cockpit canopies and astronaut helmet faceplates. ▲

The surgeon is using a self-contained instrument that needs no power source, lines or hoses, thus offers optimum freedom in the operating room. It is one of a line of cordless surgical instruments that stemmed from the developing company's work on a moon drill.

The technicians at left are preparing body fluid samples for analysis by an automatic system that detects and identifies disease-producing mechanisms in the human body. Handling as many as 240 samples at a time, it provides faster analysis – thus earlier treatment – and minimizes human error. Successful transfer of this technology, originally developed to detect bacterial contamination aboard an unmanned planetary spacecraft, resulted in formation of a new company.

A tiny mote of dust could trigger malfunction in a sensitive spacecraft system, so NASA developed contamination control technology for assembly of sensitive flight equipment in hospital-like "clean rooms." One of several offshoots of that technology base is a line of advanced, disposable, inexpensive anticontamination garments for hospitals and pharmaceutical clean rooms.

Spinoffs in

Public Safety

The field of public safety has been especially susceptible to transfer of aerospace technology. Some examples:

▲ Developed to minimize Space Shuttle fire hazard, a polyimide foam material with exceptional flame resistance is used on interior furnishings of public-use aircraft, trains and buses.

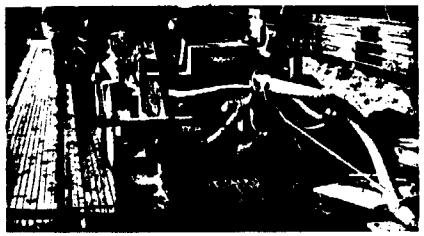
▲ Available to airport, municipal and industrial firefighters is a "bayonet-type" spray nozzle, developed for Shuttle landing emergencies, that can be thrust through the skin of a transportation vehicle or certain building materials to deliver extinguishants to the interior.

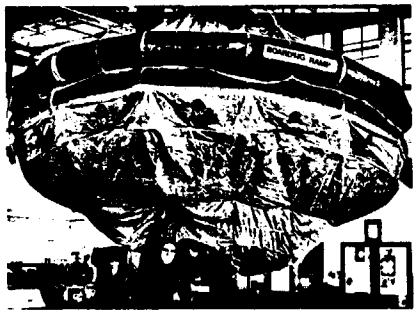
▲ A NASA-developed device for detection of invisible flames in liquid hydrogen propellant tanks has become a commercial product for use in hydrogen generating plants and pipelines.

▲ The sophisticated smoke/fire detecton system used in the Skylab manned spacecraft provided the technology for a home use detection/warning device.

▲ A special type of electronic circuitry developed for space telemetry provided technology for a supersensitive industrial gas leak detector; the same technology was later applied to a post-fire arson detection device and a visual alert system for the hearing impaired.

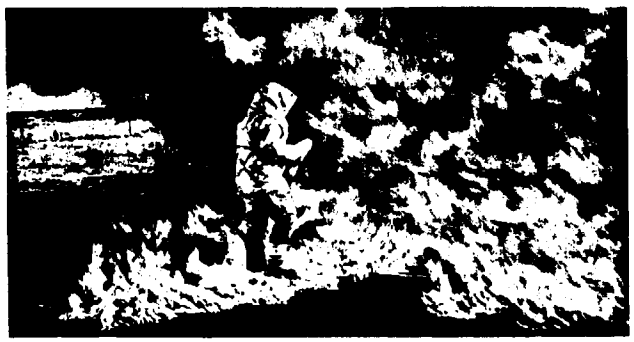
▲ An underwater device that signals the location of a downed airliner's flight recorder borrowed technology from a NASA/Navy-developed sonar search/locator system. ▲



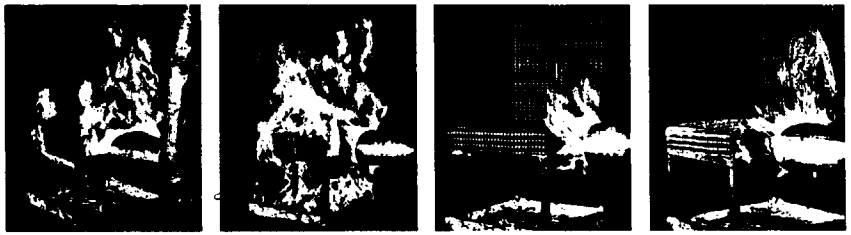


Ocean-landed Apollo astronauts waited for helicopter pickup in inflatable rafts specially stabilized to prevent overturn by the helicopter's downwash. The NASA-patented water ballast stabilization system was employed in a widely used commercial raft that does not capsize in heavy seas.

The workmen are cutting grooves in a highway surface to improve wet weather traction. Developed by NASA to curb skids of landing aircraft, the grooving technique has been applied to hundreds of airport runways worldwide and to many highways in North America, Europe and Asia.



A thin, lightweight, flexible fire-resistant fabric developed for Apollo astronauts' space suits found application in a fire-entry suit for fire-fighters and industrial workers exposed to high heat, steam or hot liquids.



The first two photos above show a conventionally covered chair after 30 and 90 seconds exposure to high temperature. The latter two photos show the effect of the same exposure on a chair covered by a fabric containing fireblocking fibers of a formula originally developed for astronaut flight suits. As is evident, the fibers curb flame spread, hence offer increased safety in a wide range of civil applications from airline seat cushions to auto racing driving suits to foundry workers protective apparel.

At left is one of several products that spun off from NASA research in x-ray telescope instrumentation, an x-ray inspection system for examining luggage at airports and other security areas. It produces high quality images at extremely low radiation dosages.

These firefighters are wearing a breathing apparatus for protection against smoke inhalation, the result of a multiorganizational development project that adapted aerospace materials and technology to a national need for lighter, less bulky firefighting equipment.

NASA design technology for "hard shell" pressure suits -- intended to protect future lunar colonists against micrometeorites -- was incorporated in this advanced deepwater diving system, which has fluidic joints to permit 75 percent normal human mobility.

Spinoffs in

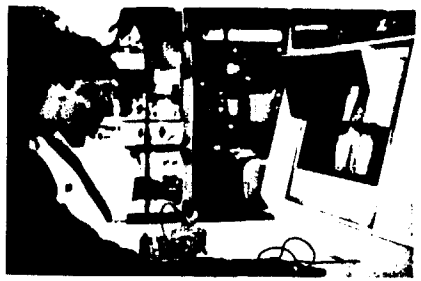
Consumer/Home/ Recreation

Echo 1, NASA's first experiment in satellite communications, was a 10-story-size balloon used as a giant reflector for "bouncing" radio signals from one point on Earth to another. For its skin, NASA needed a material that was exceptionally thin and light yet highly reflective. A NASA contractor came up with a metal-coated plastic film so fine that the balloon's skin was half the thickness of the cellophane on a cigarette package. That development triggered the growth of a whole new industry making metallized products with extraordinary heat reflection or heat retention characteristics. The technology transfer process went through a second circuit when NASA found that metallized materials were ideal for protection of spacecraft crews and components from solar radiation and extensive space use, plus additional R&D, spawned another round of spinoffs. The list of applications for consumer/home/recreational use alone is uncommonly broad—stadium blankets, tents, suntanning pads, wall coverings, drapery liners, window shades, bedwarmers, windbreakers, candy wrappings, food packaging, to mention only a few among scores—and there are many additional applications in other fields.▲

Auto racing champion Dale Earnhardt displays a "cool vest," part of a personal cooling system many drivers use to combat cockpit temperatures that often get above 130 degrees Fahrenheit. The cool suit, which includes a helmet liner, is a derivative of space suit technology.

For moonwalking safety and comfort, astronauts' lunar boots featured a three-dimensional "spacer" material for cushioning and ventilation. That material, in modified form, has turned up in a popular line of athletic shoes designed for improved shock absorption and reduced foot fatigue.

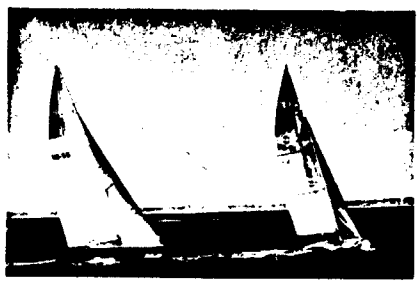
A highly reflective insulating material developed to protect spacecraft and crews from intense solar radiation became an energy-saving window insulator. A thin metallized film bonded to windows of homes, schools, office buildings and other facilities, it reflects the Sun's heat and glare outward, cutting down on energy costs for cooling.



A computerized beauty makeover system incorporates NASA image analysis technology originally developed to construct and analyze pictures of distant planets. Directed by a makeup expert, the system analyzes the client's skin color, considers thousands of makeup color combinations and offers a selection of "new looks."

This ice show troupe is performing on an "instant rink" built atop a theater stage in one day by means of a spinoff portable icemaking system. The key is an innovative flexible tube circulation system for the refrigerated coolant, an adaptation of a solar collector heat distribution network developed under NASA sponsorship.

To protect plastic surfaces of aerospace equipment from harsh environments, NASA developed an abrasion-resistant coating that found commercial application in a popular line of sunglasses. The NASA technology was combined with the company's own research to produce a long-wearing lens with scratch resistance better than glass.



Winner of the 1987 America's Cup, the racing yacht *Stars and Stripes* got an assist from NASA-developed "riblets," tiny grooves in the yacht's hull that contributed to increased boat speed. The world's largest jetliner producer is now planning to incorporate riblets in its transports to reduce air drag and improve fuel efficiency.

Spinoffs in

Environment and Resources Management

Several aerospace technologies have found spinoff utility in environmental and resources management applications. NASA-pioneered satellite survey of Earth resources, provided a technology base for commercial remote sensing networks. Space image processing is being used in geology, archeology and pipeline monitoring. And many types of aerospace instruments and materials are being employed in such areas as air quality monitoring and noise abatement. ▲

NASA's need to protect ground and flight equipment from corrosion—in particular coastal area erosion induced by salt spray—led to development of many types of coatings that have spun off to commercial use. In the photo, a bridge maintenance inspector is checking a girder covered by an inorganic coating—produced under NASA license—with superior corrosion resistance. The Statue of Liberty wears a NASA-developed interior coating and a variety of other coatings are protecting office buildings, tank farms, ships, oil rigs and other structures.

For future space colonists and long-duration space flights, NASA has extensively explored the use of aquatic plants—which absorb impurities from sewage—as a means of treating and recycling wastewater. This research has found broad civil application; dozens of small towns are using water hyacinths as their primary wastewater treatment system and one major city uses them in a secondary treatment technique. In the photo, a hyacinth aquaculture filtration tank in San Diego, California.

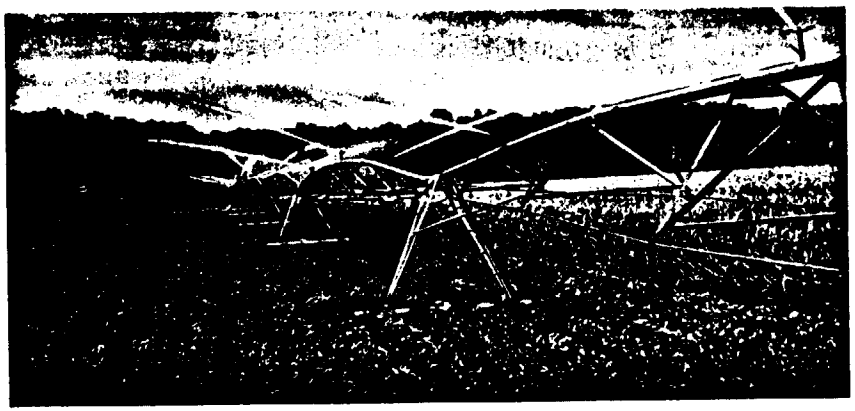
In Washington, D.C., a crew is installing a sewer monitor that tracks wastewater processing, warns of potential overload and reports how the system is functioning generally. In use in hundreds of cities, it employs multiple aerospace technologies, in particular sensors, microcomputers and redundant subsystems.

Spinoffs in

Food and Agriculture

A microwave system dries agricultural crops with less chance of quality loss and a lower energy requirement than hot-air blowers; it is a spinoff from space-simulating vacuum chamber technology. For increased hog production, some farmers are using a robotic sow—an artificial nursing machine for piglets—whose key element is a miniature heat pump developed for satellites. These are examples of many widely varied aerospace spinoffs in food and agriculture; a few more are illustrated.▲

Not your ordinary fishing net is the one pictured; it is a spinoff seine that sinks faster and arrives at its fishing depth quicker than conventional nets, thus traps extra tons of fish that would otherwise dart away. The key is a superstrong twine and a twisting process first used in a safety net for personnel working on the Space Shuttle.



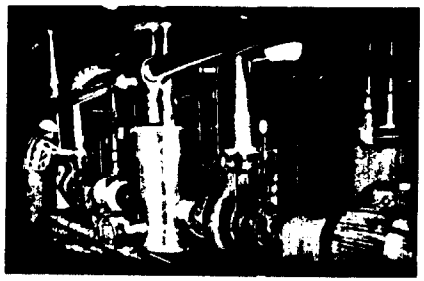
This irrigation system rotates around a center pivot, watering multi-acre areas in a single revolution. Each three-ton wheeled "tower" has its own electric motor; power is transmitted to the wheels by individual gear boxes that incorporate NASA technology to protect them from wear and heat stress.

More than a decade of research by NASA and the Department of Agriculture brought a solution to a major crop dusting problem: wasteful and environmentally unacceptable drift of chemicals beyond target areas. The answer, a complex computer program that considers all variables and provides information on how to adjust spray height, nozzle position or other factors to get the desired coverage with minimal drift.

Spinoffs in

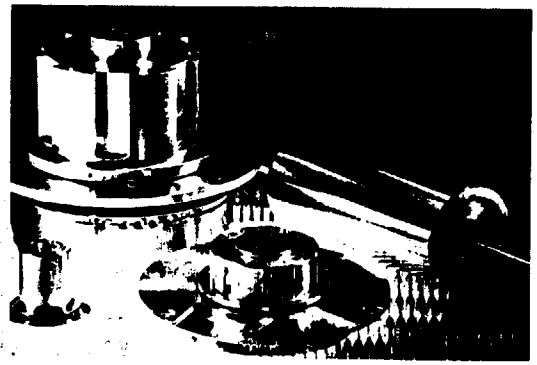
Manufacturing Technology and Industrial Productivity

Among examples of aerospace technology being put to productive use in industrial facilities are an air flotation system that allows heavy loads to "float" over the plant on air bearings, an adaptation of the method used by NASA to move multi-ton launch vehicle segments; use of the material in Space Shuttle thermal tiles as an insulator for the heating chambers of a high temperature laboratory system; and a NASA-developed system that facilitates robotic welding by employing closed-circuit TV to guide an arc welding torch without human intervention. Some other examples are pictured. ▲



To increase the thrust of liquid fuel rockets, NASA developed an "inducer" to boost the flow rate of rocket fuel pumps. A pump manufacturer used the NASA technology to increase the speed of special purpose pumps such as the one shown, which is used to recirculate wood molasses.

Pictured above is a batch of microspheres, plastic beads so tiny that a vial as long as an index finger can hold 15 million of them. Perfectly spherical because they were grown in gravity-free space, they serve as important need among industrial laboratories and manufacturing facilities as reference standards for calibrating instruments with extreme accuracy.



In the photo are a variety of ferrofluid bearings. Ferrofluids are liquids provided with magnetic properties. They had their origin in the space program when scientists experimented with drawing weightless fuel into a rocket engine by magnetizing it. NASA licensed the technology to a company formed specifically to commercialize it. Ferrofluids offer unique advantages in manufacture of electronic products, industrial processes, medical equipment, visual displays, automated machine tools and a wide range of other applications.

Spinoffs in

Energy

Space-pioneered solar energy technology has found wide usage in Earth heating, cooling and electricity-generating applications. Among other spinoff technologies are heat pipes used to cool spacecraft electronics and a variety of techniques originally designed to minimize energy use in aircraft and spacecraft, now serving the same purpose in Earth applications. Among unusual spinoffs are the employment of space telemetry in an automatic oil well production reporting system, and the use of space-developed power amplifiers to reduce TV stations' transmission costs. ▲

The aluminized "heat shield" being applied holds out or keeps in heat, cold air and water vapors. Once used as a radiant heat barrier in Apollo and other spacecraft, the heat shield insulation is the key element of a sophisticated energy conservation technique for homes and office buildings that offers dramatic energy savings and is finding rapidly increasing acceptance in the U.S.

Within the upright supports of the Alaska pipeline are some 76,000 heat pumps, compact, no-moving-parts devices that, in space use, alternately heat or cool spacecraft components subjected to varying temperatures. In Alaska, the permafrost soil alternately freezes and thaws. That could weaken the pipeline's support structure—except for the heat pipes; they keep the ground near the pipeline permanently frozen, protecting against pipeline ruptures that could cause economic loss or environmental disaster.

To conserve energy in aerospace systems, NASA developed a controller for electric motors that senses a motor's load and feeds it only the minimum voltage it needs to do its job—hence sharply cuts power wastage. Installed in manufacturing facilities—such as the home products conveyor line pictured—it can save big companies millions a year in power costs.

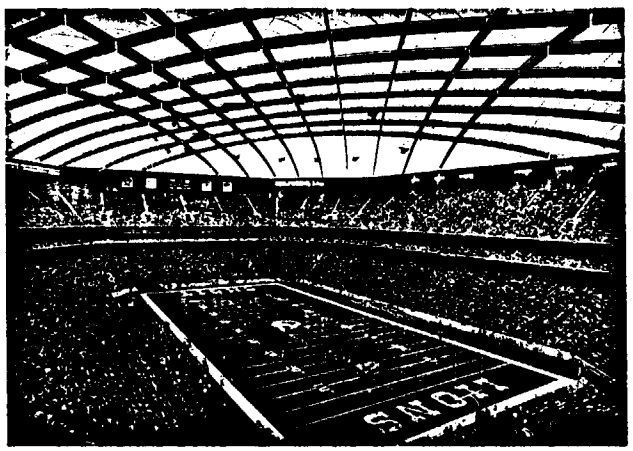
Fabric structures and flat conductor cable for building electrification are examples of extraordinary spinoff benefit to the field of construction, but there are many others that offer important gains in economy, safety and construction simplification.

A random selection:

▲ NASA's long experience in fracture toughness testing for aerospace hardware contributed to safety-enhancing test procedures and requirements for all U.S. federal-aid highway bridges.

▲ An aluminum color finish that improves the weather resistance and attractiveness of commercial buildings is based in part on an anodizing process developed to produce a hard protective finish for spacecraft exterior surfaces.

▲ Developed for measurement of bolt stress in wind tunnels, a NASA bolt monitor provides extremely precise information on bolt tensioning in construction jobs and reduces chance of serious accidents caused by overtightened or undertightened bolts. ▲



In the 1960s, two contractors teamed to produce a special fabric for space suits that was thin, light, flexible, yet durable and noncombustible. The material provided the basis for later development of heavier, construction-use fabrics with similarly advantageous properties. The first adaptation was Michigan's Silverdome (left). Their relatively low cost has inspired widespread acceptance of fabric-roofed structures in shopping malls, stadiums, field houses, schools, theaters, exhibit halls and industrial facilities. American companies are also taking the technology abroad; in the upper photo is the Haj Terminal at King Abdulaziz International Airport in Saudi Arabia.

Use of flat conductor cable (FCC)—rather than round cable—to reduce the size and weight of aircraft and spacecraft systems sounds like a simple switch but it took years of research. NASA subsequently applied that know-how in a multiyear, multi-organizational effort to adapt the technology to design of electrification systems for commercial buildings and obtain approval from fire protection and insurance authorities. Offering speedy installation, reduced cost of rewiring and simplified building construction, use of FCC has expanded rapidly since the first commercial installation in 1979. Above left, an undercarpet installation. With wiring out of sight and no vertical wiring enclosures needed, interior designers have new latitude in planning attractive "open landscape" office layouts such as that in top center.

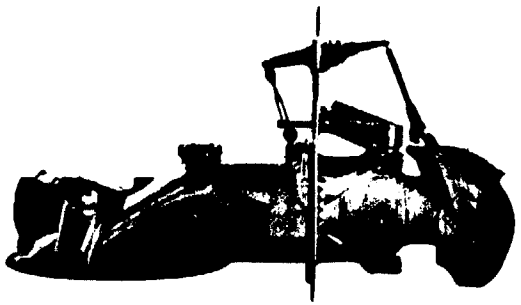
Strong winds can cause a lot of problems for buildings, particularly tall buildings, so architects are increasingly employing "wind engineering," a relatively new discipline that involves testing models of new buildings in wind tunnels. In the photo, a leading wind engineer is setting up a test in a university wind tunnel; his special technique incorporates NASA predictive technology for comparing simulated with actual wind flows at levels below 2,000 feet.

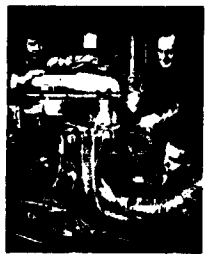
A line of cordless tools and instruments based on technology developed for a lunar subsurface drill includes self-contained construction tools for use where a power source is not readily available.

Spinoffs in

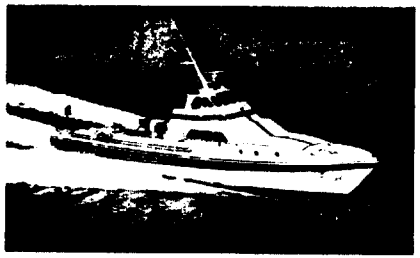
Transportation

Many of the aerodynamic, propulsion and other advances that have made American-built airliners the most widely operated in the world originated in NASA aeronautical research. NASA also applies aviation-acquired propulsion expertise to automotive research. And many other aerospace technologies have found adaptation, via the spinoff route, in surface transportation applications.▲





In cooperation with truckers, engine manufacturers, and other government agencies, NASA is developing — for cars, buses and trucks — an advanced Stirling external combustion engine that offers dramatically lower fuel consumption and environmental gains in reduced noise and exhaust emissions.



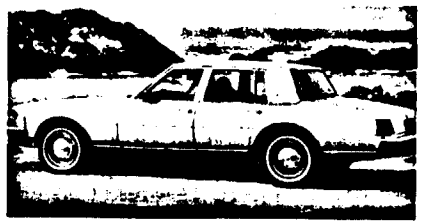
The mighty turbopumps of the Saturn V moonbooster fed fuel to the launch vehicle's engines at the rate of 200,000 gallons a minute. The turbopumps (above) later found commercial utility as primary propulsion systems in a type of high speed crewboat and supply vessel (left) for the offshore oil industry.

The Space Shuttle's sophisticated, computerized propellant management system, especially designed to monitor the flow of supercold cryogenics, provided the technology for a system that measures precisely the cryogenics loaded and offloaded by liquefied natural gas tankers like the one pictured.

Spinoffs in

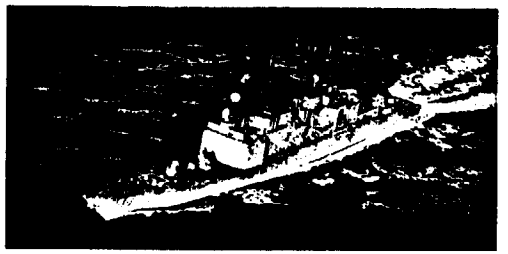
Structural Analysis

For years, aerospace engineers have employed a design technique in which they create mathematical models of an airplane or space vehicle and "fly" it by means of computer simulation; that enables them to study the behavior of a number of different designs before settling on a final configuration. For this technique, NASA developed the NASTRAN program—NASA Structural Analysis—which takes an electronic look at a computerized design and predicts how the structure will perform under service use conditions. Quick and inexpensive, it minimizes trial and error in the design process, this has become one of the most widely employed spinoffs, used to analyze autos, trucks, railroad cars, ships, nuclear reactors, steam turbines, bridges, rollercoasters, office buildings and hundreds of other structures.▲



A decade ago the U.S. auto industry began designing cars with help from the NASA-developed NASTRAN program. Today the NASTRAN program is incorporated in the computer design processes of several major auto companies.

A machinery manufacturer used the NASTRAN program to design these steam turbines. A predictive tool, NASTRAN analyzed the dynamic behavior of turbine components, allowing substantial savings in development costs.

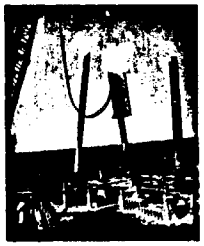


A major shipbuilder used the NASTRAN program in designing the U.S. Navy's *Kidd Class* destroyers, one of which is pictured, and the *CG-47 Class* of guided missile cruisers.

In the photo, a mammoth valve for a nuclear power plant is undergoing shock and vibration testing on a "shake table." In designing a line of valve products, the manufacturer uses the NASTRAN program to identify high stress areas and to establish design adequacy under the most severe conditions the valve might encounter in service use, including earthquakes.

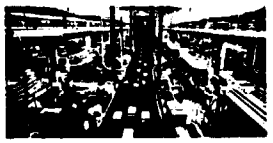
NASA and other government agencies develop many types of computer programs that frequently can be adapted—with little or no modification—to secondary uses, often remote from their original purpose. In the interest of national productivity, NASA's Computer Software Management and Information Center (COSMIC) offers adaptable programs to industry at a fraction of their original cost. Since a customer gets a return many times the investment, COSMIC's service has become one of the broadest areas of spinoff applications. COSMIC offers some 1,400 programs and their potential secondary uses would fill a catalog; the illustrations show a few of the many examples.▲

A COSMIC software package helps an insurance company catch data processing errors before they affect the company's customer service or its profitability.



A COSMIC-supplied computer program is used in an offshore oil industry project aimed at developing a capability for predicting the best pile driving technique for each new offshore platform.

How various chemical structures will hold up when used in plastic products—like the containers shown—is analyzed by COSMIC software supplied to a manufacturer of chemical compounds for plastics.



Two COSMIC computer programs that predict noise levels of machinery were employed in a noise analysis performed for a tobacco company that sought to reduce noise so its employees would not have to wear ear protection devices.

A waterfowl preservation society uses NASA-developed software to interpret satellite data on the continually changing conditions of waterfowl habitats.

NASA Technology Transfer System

NASA's system of technology transfer personnel and facilities extends from coast to coast and permits geographical coverage of the primary industrial concentrations in the United States, together with regional coverage of state/local government transfer activities. Main elements of the system include Technology Utilization Officers (TUOs) at nine NASA field centers, who manage their center's participation in technology utilization matters, and 10 Industrial Application Centers (IACs), which provide information retrieval services and assistance in applying technical information to user needs. TUO and IAC contacts are listed below. For information about other NASA technology transfer services, contact the Director, Technology Utilization Division, NASA Scientific and Technical Information Facility, Post Office Box 8757, Baltimore, Maryland 21240.

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Mr. Vernon B. Greenwell
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John F. Kennedy Space Center
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IAC Directors

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Mr. J. Ronald Thornton
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(800) 354-4832 (FL Only)

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Mr. J. Bonner Ware, Jr.
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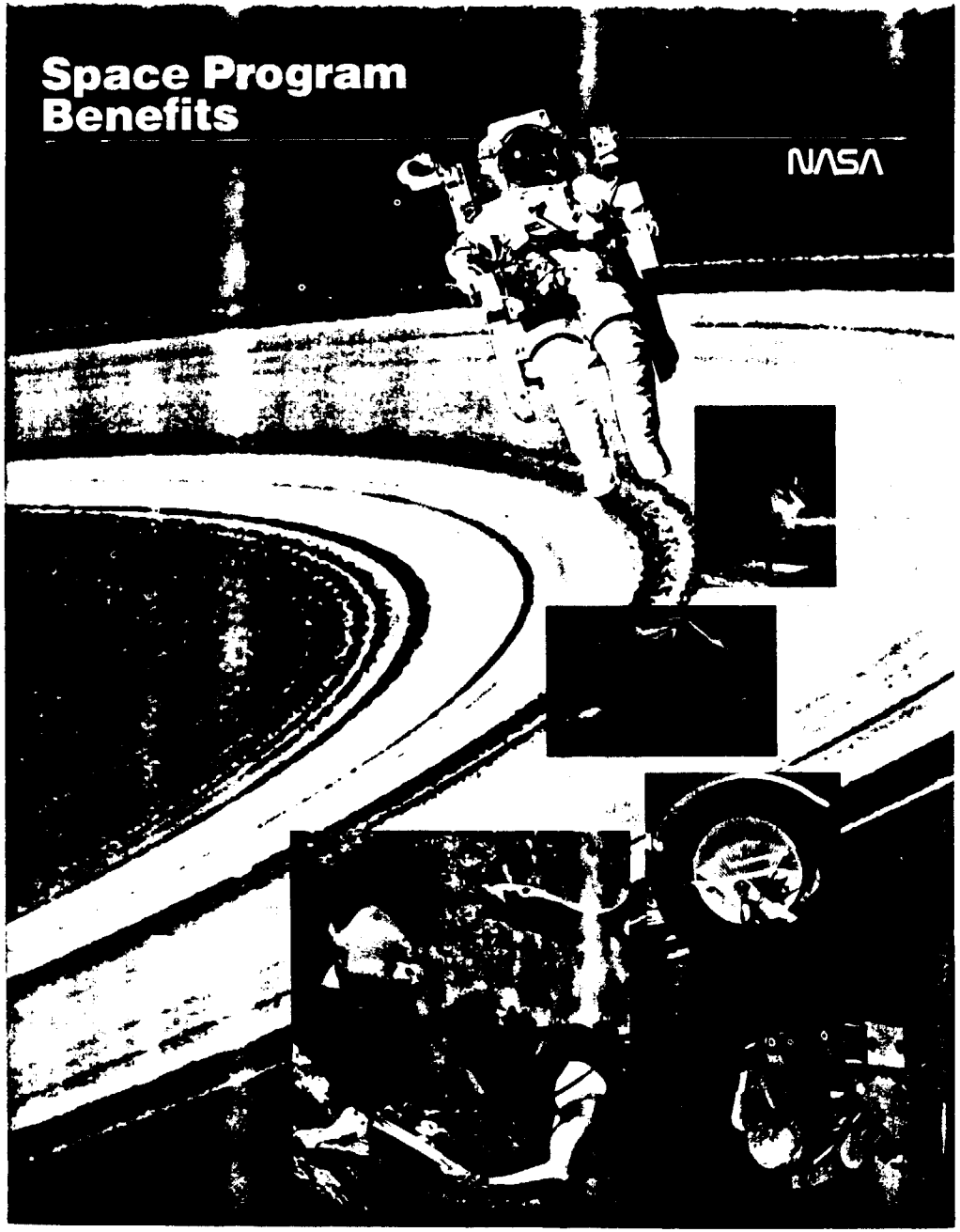


Q. What does an insulin infusion pump have in common with a wastewater recycling technique and scratch-resistant eye glasses?

A. Each is the result of "spinoffs" of aeronautics and space research.

Spinoffs are technologies which have been transferred to uses different than, and often remote from, their original application in the aerospace field. It is difficult to find a facet of everyday life into which spinoffs have not penetrated, even though sometimes their origins in aerospace research are not easily recognizable. Yet, many Americans are unaware of either the existence of these breakthroughs or how they might find out more about those in which they may have an interest or need.

This publication briefly describes a sampling of the more than 30,000 applications of space technology over the past 27 years, and lists an authoritative source for further information on these and other aerospace benefits.

To meet the goals of space exploration and aeronautical development, the National Aeronautics and Space Administration (NASA) and the aerospace industry have developed innovations in virtually every field of science and technology. This storehouse of knowledge provides an extremely broad technical foundation for the stimulation of secondary applications of these unique developments. The following are cited as examples of how this research is providing other benefits for life here on Earth.

Insulin Infusion Pump

Insulin-dependent diabetics have for years been tied to a rigid schedule, in which mealtimes, sleep time and exercise had to be timed to insulin injections. Today, some 12,000 diabetics are free from such lifestyle restrictions through the use of "pump therapy."

Pump therapy involves the use of an external pump to deliver insulin continuously at a preprogrammed, correct rate. The pump wearer can lead a more normal existence, even participate in sports or travel. In addition, research has shown that infusion of "short acting" insulin in tiny amounts over a long period—instead of multiple daily injections of long-acting insulin—has helped many diabetics achieve better control of blood sugar levels, thereby minimizing the possibility of complications.

One example of the pump system, is not much larger than a credit card and weighs only 3.8 ounces. The compact package houses a microprocessor, a long-life battery, a reservoir for the insulin and a syringe. The syringe is connected to an infusion set, which consists of a thin, flexible plastic tube about 30 inches long with a needle at its end.

The patient inserts the needle beneath the skin, usually in the abdomen. Clipped to a belt or just about any part of the wearer's clothing, the minipump infuses insulin at either the "basal rate" (continuous delivery) or "bolus rate" (larger amounts of insulin administered prior to meals or when blood sugar levels are elevated). The system can be programmed with up to four basal rates, which is important to patients whose insulin requirements change during the course of the day. Potential users of the pump should, of course, consult their physician as to the individual application of this system.

Reading Machine for the Blind

A device which converts regular inkprint into a readable, vibrating form that is perceptible to the sense of touch enables blind persons to read almost anything in print, not just braille transcriptions. The device is called the OPTACON, or OPtical-to-Tactile-CONverter. It combines optical and electronic technology developed in aerospace research.

A blind reader moves a miniature camera across a line of print with one hand, and with the fingers of the other hand senses a vibrating image of the letters the camera is viewing on a special screen.

For school use, the OPTACON makes the instructional materials of the sighted available to the blind. It also helps the sightless to obtain jobs, win promotions and enter vocational areas once closed to them.

A related spinoff of optical-electronic technology is the Paper Money Identifier. A small device the size of a cigarette pack, this device can scan a piece of paper money, react to the different colors and unique design features of the bill and generate an audible signal identifying the denomination.

Vehicle Controller for the Handicapped

For the Apollo lunar landings of the early 1970s, NASA developed a Lunar Rover vehicle to permit exploration of the moon miles from the immediate vicinity of the landing site. The Rover was designed to allow an astronaut to drive one-handed, using an airplane-like joystick to accelerate, brake and steer the vehicle. That technology is being applied to a system that offers severely handicapped people an opportunity to drive highway vehicles, thereby providing them mobility for more productive lives.

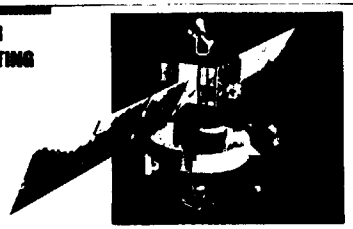
Called Unistik, the vehicle's control system employs a joystick that combines the functions of steering wheel, brake pedal and throttle pedal, permitting it to be driven by handicapped persons who have no lower limb control and only limited use of their arms. The driver simply moves the joystick forward to accelerate, backward to brake and from side-to-side for steering; any combination of these movements can be used. The Unistik system can be adapted to an ordinary vehicle.

New Window into the Human Body

Magnetic Resonance Imaging (MRI) employs magnetic field and radio waves to peer inside the body. Unlike x-rays, MRI can "see" into bones. But MRI observations are more difficult to interpret than x-rays, which has limited their usefulness.

By applying the computerized image enhancement technology developed to read Earth resources satellite photographs, experts are now able to provide thematic "maps" of the human body. False color can be added to each type of tissue, making such problems as tumors or blood clots stand out clearly. MRI enhancement provides invaluable information to diagnostic physicians and surgeons.

Weather Forecasting



Another direct benefit from aerospace advancements has been the forecasting of world-wide weather conditions through meteorological satellites. In operation for more than 25 years, weather satellites orbit the Earth, producing current data on weather changes for the National Weather Service. These satellites not only make it possible to understand our environment better, they also help to protect us from its dangers.

In 1900, long before the advent of weather satellites, a major hurricane struck the Gulf Coast city of Galveston, Texas, with an estimated 6,000 lives lost. Most of the deaths were directly attributable to lack of advance warning and information on the severity of the storm.

A similarly destructive hurricane struck the Mississippi Gulf Coast in 1969, with some $1.4 billion in property damage, yet, thanks to weather satellite forecasts, only 256 people lost their lives, and most of those could have been spared if they had heeded the early warnings to evacuate the area.

Voice-Controlled Wheelchair and Manipulator

Based on teleoperator and robot technology developed for space-related programs, a voice-controlled wheelchair and its manipulator have been tested as a possible aid to paralyzed and other severely handicapped persons.

The heart of the system is a voice-command analyzer, which utilizes a minicomputer. The patient repeats a command several times into a microphone connected to the computer. Thereafter, the analyzer recognizes commands only in the patient's particular speech pattern. The computer translates commands into electrical signals which activate appropriate motors and cause the desired motion of chair or manipulator. The manipulator can pick up objects, open doors, turn knobs and perform a variety of other functions.

Speech Autocuer

The development of a wearable, real-time speech perception aid has the potential to improve the quality of life for many of the 1.8 million deaf people in the United States. Research has been completed which demonstrates that deaf people can perceive speech accurately through a prosthesis based on "cued speech."

Called the Autocuer, the speech analyzing device presents automatically-derived visual cues in real-time to a wearable eyeglass display which, in combination with lip reading, enables accurate speech perception by deaf people.

The Autocuer project is an example of government, industry and a college working together to develop, in this case, a low-power, wearable microcomputer to analyze connected speech for successful automated cuing. Support for this project was provided by NASA and the Veterans Administration.

Water Recycling

For more than a decade, the National Space Technology Laboratories (NSTL) at Bay St. Louis, Mississippi, has been conducting research on the use of aquatic plants—principally water hyacinths—for the treatment and recycling of wastewater. Already serving a number of smaller towns, the "aquaculture" technique has been adopted by the City of San Diego, California, and Disney World's Epcot Center at Orlando, Florida.

In the early 1970s, NSTL discovered that the glossy green water hyacinths literally thrive on sewage; they absorb and digest nutrients and minerals from wastewater, converting sewage effluents to clean water. Thus, they offer a means of purifying water at a fraction of the cost of conventional sewage treatment facilities.

Scratch-Resistant Glasses

When the Food and Drug Administration issued a regulation in 1972 that all sunglasses and prescription lenses had to be shatter-resistant, the use of plastic lenses increased dramatically.

Today, the majority of sunglasses, corrective and safety lenses sold in the United States are made of plastic. But, while plastic lenses are lightweight and offer better absorption of ultraviolet rays than glass, many types of plastic lenses developed visibility-reducing scratches. Until recently, the best plastic available fell far short of glass in scratch resistance.

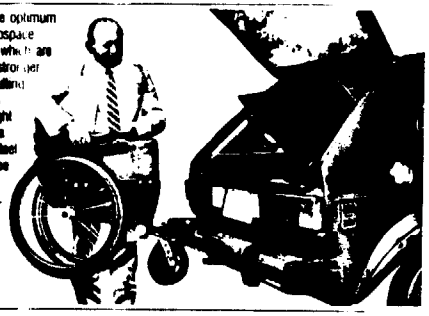
One major producer of sunglasses spent more than a decade in search of a coating that would provide plastic lenses with glass-like scratch resistance, while maintaining the advantageous properties of plastic. The solution combined space technology with that of the sunglass producer.

The contribution of space technology was a highly abrasion-resistant coating developed as a means of protecting plastic surfaces of aerospace equipment from harsh environments. The new lens became commercially available in 1984.

Advanced Wheelchair

More than one million people in the United States rely on wheelchairs for mobility and many of them have difficulty with existing types of chairs. Problems include frequent breakdowns, limited lifetime and lack of portability.

Most efforts toward improving wheelchair designs have focused on improving components, rather than on developing an entirely new chair. To address the overall needs of wheelchair users, the Langley Research Center, Hampton, Virginia, teamed with the University of Virginia's Rehabilitation Engineering Center in developing a new wheelchair concept. Researchers employed aerospace computerized structural analysis techniques to arrive at the optimum design and used aerospace composite materials, which are generally lighter but stronger than metals. The resulting 25-pound chair offers the strength and weight bearing capability of a 50-pound, stainless steel wheelchair, and can be collapsed for auto storage and transport.



Laser Heart Surgery

One technology transfer from aerospace research that may some day eliminate or significantly reduce the need for coronary bypass surgery is the combined use of lasers and fiber optics.

It is estimated that some five million Americans are afflicted with atherosclerosis, the single biggest cause of cardiovascular disease. Atherosclerosis is the buildup of fatty and fibrous deposits that block the arteries carrying blood to the heart.

Physicians at Los Angeles' Cedar-Sinai Medical Center and scientists at the Jet Propulsion Laboratory in Pasadena, California, jointly developed a laser system to non-surgically clean clogged arteries with unprecedented precision.

While still in the experimental stage, the procedure involves threading a 1.5 millimeter diameter catheter through coronary arteries. The laser light is carried through one of three "bundles" of fiber optics within the bendable catheter.

Another group of fibers shines a light at the tip to provide video pictures of the inside of the artery. Watching the video pictures fed through the fiber optics, the physician can spot areas of plaque build up in the artery and fire short bursts of laser beams to vaporize or disintegrate the plaque. The process occurs so quickly that neighboring tissue is spared from damage.

New Flame-Resistant Materials

Research into developing advanced flame-resistant materials to minimize fire hazards in the Space Shuttle resulted in a new, lightweight substance that strongly resists ignition. When exposed to open flames, it only chars and decomposes. In one form, it can be used for seat cushions, in a harder form for door, wall, floor and ceiling panels. It has particular application to airplanes, ships, buses and rapid transit cars, where toxic smoke produced from burning materials is often the major cause of fire fatalities. This safer material is now commercially available.

Space technology also contributed to the development of a new type of smokeless wire and cable insulation. In several subway fires, burning wire and cable spread the flames, creating much hazardous smoke. Borrowing from solid rocket propellant technology, NASA developed an insulating material that is less likely to burn, and would produce less smoke if it did. A line of these cable assemblies is being supplied to mass transit systems in the United States and abroad.

Dental Braces

Straightening teeth is a difficult process, requiring months, often years, of applying corrective pressure by means of arch wires, better known as braces, which may have to be changed several times during the course of treatment. A new type of arch wire material, called Nitinol, is helping to reduce the number of brace changes, due to its exceptional elasticity.

An alloy of nickel and titanium, Nitinol was originally developed for aerospace applications. Because of its ability to return to its original shape after bending, antennas or other hardware could be compacted effectively in a satellite during launch and later expand to full size when in orbit. This same property allows braces made of Nitinol to exert continuous pull on teeth, reducing the frequency of office visits to change or adjust braces and, in some cases, actually trimming overall treatment time.

Search and Rescue

Although not a pure spinoff, one significant space benefit has been the COSPAS/SARSAT satellite system designed to aid in the speedy search and rescue of victims in downed airplanes, capsized boats and other emergency situations.

Founded by the United States, Canada, France and the Soviet Union, other participating countries now include Bulgaria, Denmark, Finland, Norway and the United Kingdom.

In practice, the satellites "listen" continuously on emergency frequencies used by ships and aircraft. When a beacon alert is received from a craft or vehicle equipped with an emergency transmitter, the satellite relays the signal to a specified ground-based facility. Within minutes, a computer will identify the location of the transmitting source within a three-mile area. Rescue coordination centers are then notified of the emergency and its location for guidance of search and rescue craft.

Since this international cooperative program was begun in September 1982, more than 850 lives have been saved from boating, aircraft and automotive incidents.

Anti-Corrosion Paint

Because of exposure to salt spray and fog, coastal or ocean structures—such as bridges, pipelines, ships and oil rigs—require more corrosion protection than is needed inland. One study found that anti-corrosion coatings with a 25-year lifetime inland were good for only a few years in coastal areas.

Seeking to reduce maintenance costs for gantries and other structures at the Kennedy Space Center located on Florida's Atlantic Coast, the Goddard Space Flight Center, Greenbelt, Maryland, conducted research aimed at developing a superior coating that would not only resist salt corrosion, but would also protect launch structures from the very hot rocket exhaust and the thermal shock created by rapid temperature changes during launch of space vehicles. The successful research resulted in a new type of inorganic coating that is being marketed commercially today.

The easily applied paint, which incorporates a high ratio of potassium silicate, is water-based, non-toxic, non-flammable and has no organic emissions. In addition, the formulation bonds to steel and, in just 30 minutes, creates a hard ceramic finish with superior adhesion and abrasion resistance.

Advanced Turboprop

Although jetliner fuel costs have moderated in recent years, they are still several times what they were before the oil crises of the 1970s. Today, fuel accounts for some 30 percent of an airline's total operating costs and future prices are uncertain. For this reason, there has been a revival of interest in the turbine/propeller engine; its drawback has been that propeller tip speed limitations have held down airplane speeds.

For several years, the Lewis Research Center in Cleveland, Ohio, has been working to develop technology for "propfan" systems that could be available to aircraft manufacturers in the early 1990s. Propfan designs feature extremely thin propeller blades that sweep back away from the direction of rotation to provide greater efficiency at high tip speeds. The blades are also shorter than those of conventional propellers, so the tips do not have to move as fast for a given speed requirement.

Wind tunnel tests have shown that propfans driven by advanced engines could power commercial transports to speeds comparable with those of existing subsonic jetliners at fuel savings on the order of 30-to-40 percent.

Breathing System for Firefighters

Firefighting and fire prevention are areas of activity that have been major users of aerospace spinoffs. In recent years, this technology has been beneficially transferred to such applications as a portable firefighting module; protective outergarments for workers in hazardous environments; a broad range of fire-retardant paints and foams; fireblocking ablative coatings for outdoor structures, and a number of types of flame resistant fabrics for use in the home, office or in public transportation vehicles.

Perhaps the broadest fire-related technology transfer is the breathing apparatus worn by firefighters for protection from smoke inhalation injury. Breathing equipment widely used throughout the United States is based on space development of the 1970s.

The effort began in 1971 in response to a need expressed by many of the nation's fire chiefs. The traditional breathing system was heavy, cumbersome, mobility-restricting and so physically taxing that it often induced extreme fatigue. Many firefighters preferred not to use the equipment. As a result, smoke inhalation injuries were on the rise.

In cooperation with the Fire Technology Division of the National Bureau of Standards, the Johnson Space Center in Houston, Texas, developed a breathing system weighing slightly more than 20 pounds, about one-third less than existing systems, with a reduced profile design intended to improve the mobility of the wearer. The system included a face mask, frame and harness, a warning device and an air bottle. Today, every major manufacturer of breathing apparatus is producing units that incorporate space technology in some form.

NASA National Aeronautics and Space Administration

For further information on these and other technology transfers from aerospace research, write:

Centralized Technical Services Group
NASA Scientific and Technical Information Facility
P.O. Box 8757
Baltimore/Washington International Airport
Maryland 21240

There is an annual, illustrated publication on spinoff technology called *Spinoff 1980, Spinoff 1981*, etc. This publication updates all of the technological achievements of each year. For information on how to acquire this book, write to the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402

BACKGROUND DATA AND INFORMATION

This section includes two documents which shed light on the impact of NASA's programs on the United States. This section includes:

- "Semiannual Procurement Report: Fiscal Year 1990," selected pages; Office of Procurement, NASA; April 1990.

- "The Private Sector Economic and Employment Benefits to the Nation and to Each State of Proposed FY 1990 NASA Procurement Expenditures," all pages; prepared for the NASA Alumni League by Management Information Services, Inc., of Washington, D.C.; April 1989.

Semiannual Procurement Report

Fiscal Year 1990

October 1, 1989 - March 31, 1990

NASA
National Aeronautics and Space Administration

INTRODUCTION

This report presents summary data on all NASA procurement actions and detailed information on contracts, grants, agreements and other procurements over $25,000 awarded by NASA during the first six months of Fiscal Year 1990.

The dollar value on procurements over $25,000 amounted to 98 percent of the total dollar value of procurement actions completed during the first six months of Fiscal Year 1990. However, these larger procurements accounted for only 22 percent of the total actions.

Procurement action, as used in this report, means contractual actions to obtain supplies, services or construction which increase or decrease funds. A procurement action thus may be a new procurement, or modifications such as supplemental agreements, change orders, or terminations to a contract that change the total amount of funds obligated. An obligation is a contractual commitment to pay for supplies or services that are specified in the contract.

The report was prepared by the Procurement Management Division, Office of Procurement, NASA Headquarters. Inquiries should be addressed to:

National Aeronautics and Space Administration
Office of Procurement (Code HM)
Washington, D.C. 20546

SUMMARY

NASA's procurements during the first six months of Fiscal Year 1990 totalled $6,563.5 million. This is 12.3 percent more than was awarded during the corresponding period of Fiscal Year 1989 (for further detail see Page 4).

Approximately 80 percent of the total awards were placed directly with business firms, 9 percent with the California Institute of Technology for operations conducted by or through the Jet Propulsion Laboratory, 4 percent with educational and other nonprofit institutions or organizations and 6 percent with or through other Government agencies (Page 5).

Eighty percent, or $4.3 billion, of the $5.3 billion total procurement awards available for competition were made on a competitive basis. Of the total awards available for competition, $260 million, or 4.9 percent, represented competitive new awards, and $4.0 billion, or 75.4 percent, constituted within-scope modifications (incremental funding actions and change orders) to contracts awarded competitively in prior years. Approximately $813 million, or 15.3 percent, of the total awards were noncompetitive. Of these, $111 million, or 2.1 percent, of the total available for competition represented new noncompetitive awards, and $702 million, or 13.2 percent, constituted other than competitive modifications to contracts awarded in prior years. In addition, $232 million, or 4.4 percent, of the total available for competition represented follow-on awards to companies that had been previously selected on a competitive basis (Page 9).

With respect to contract types, awards on contracts having cost-plus-award-fee provisions amounted to 62 percent of the total awards over $25,000 to business firms. Incentive contracts, both cost-plus-incentive-fee and fixed-priced-incentive, accounted for 20 percent of total awards. Awards on cost-plus-fixed-fee contracts accounted for 9 percent of the total. Firm-fixed-price contracts constituted 8 percent of the total (Page 13).

Small business firms received $399.8 million or 8 percent of NASA's direct awards to business firms. This percentage reflects the fact that most of the awards to business firms were for large continuing research and development contracts for major systems and major items of hardware. Of the total new contract awards of $345.0 million to business firms during the six month period, small business firms received $76.0 million or 22 percent (Page 14). Included in the small business total were NASA awards of $26.7 million to small and small disadvantaged business through the Small Business Innovation Research Program (Page 16).

In addition to receiving prime contract awards of $399.8 million, small business concerns received $676.8 million in NASA

subcontracts from major prime contractors, including the Jet Propulsion Laboratory (JPL), and certain educational and nonprofit institutions. Thus, a total of $1,076.6 million in NASA prime and subcontract awards accrued to small business firms during the first six months of this fiscal year (Page 19).

Disadvantaged firms received $282.3 million of the $1,076.6 million awarded to small business firms in prime and subcontract awards. The $282.3 million comprised $38.5 million direct awards, $97.3 million under Section 8(a) of the Small Business Act and subcontract awards of $146.6 million (Page 19). In addition, small business firms owned and controlled by women have participated in NASA's procurement program and have received prime contract awards totalling $30.6 million, while labor surplus area preference awards totalled $7.6 million (Page 21).

During the six months, 49 states and the District of Columbia participated in NASA's awards over $25,000. These larger awards went to 1,438 business firms in 45 states and the District of Columbia and to 353 educational and nonprofit organizations in 47 states and the District of Columbia (Page 23).

Note: In this report, all tables and charts present data on total procurements of the types specified in the respective sections. Where the information is limited, e.g., to contracts over $25,000, such limitation is indicated by footnotes.

NASA PROCUREMENTS
OCTOBER 1, 1989 - MARCH 31, 1990

I. TOTAL PROCUREMENTS

NASA's procurements for the first six months of Fiscal Year 1990 totalled $6,563.5 million. This is $721.2 million or 12.3 percent more than was awarded during the corresponding period of Fiscal Year 1989.

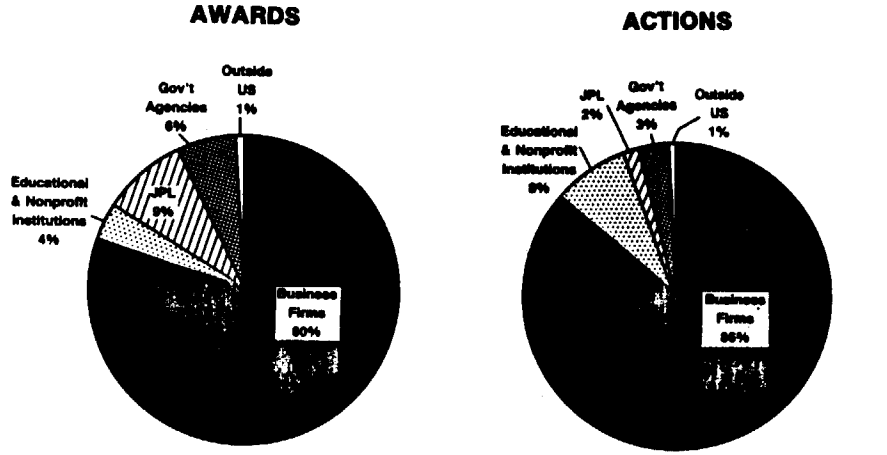
The number of procurement actions totalled approximately 52,352, an increase of 8.6 percent over the corresponding period of Fiscal Year 1989.

II. AWARDS BY TYPE OF CONTRACTOR

The distribution of NASA's procurement obligations during the first six months of Fiscal Year 1990 is shown in Figure 1. Awards to business firms accounted for 80 percent of the total obligations. These awards totalled $5,245.6 million which is $836.5 million more than the first six months of Fiscal Year 1989. Awards on contracts with California Institute of Technology for operations conducted by or through the Government-owned Jet Propulsion Laboratory amounted to $618.9 million, $153.4 million or 19.9 percent less than the first six months of Fiscal Year 1989. Awards, including grants and agreements, to educational and other nonprofit institutions totalled $298.7 million, $34.2 million or 10.3 percent less than in the first six months of Fiscal Year 1989. Procurements placed through other Government agencies totalled $355.6 million, $67.7 million or 23.5 percent more than the first six months of Fiscal Year 1989. The distribution of procurement obligations made by NASA field installation procurement offices is shown on Page 6.

AWARDS BY TYPE OF CONTRACTOR

OCTOBER 1, 1989 - MARCH 31, 1990



	(Millions)
Total	$6,563.5
Business Firms	5,245.6
Educational Institutions	211.6
Nonprofit Organizations	87.1
JPL	618.9
Government Agencies	355.6
Outside United States	44.7

	(Thousands)
Total	52.4
Business Firms	45.2
Educational Institutions	3.0
Nonprofit Organizations	1.1
JPL	1.0
Government Agencies	1.8
Outside United States	.3

Figure 1

U.S. GEOGRAPHICAL DISTRIBUTION
OF NASA PRIME CONTRACT AWARDS
OCTOBER 1, 1989 - MARCH 31, 1990

STATE	TOTAL (THOUSANDS)	BUSINESS (THOUSANDS)	EDUCATIONAL & NONPROFIT (THOUSANDS)
TOTAL	$5,464,781	$5,168,527	$296,254
ALABAMA	556,084	546,275	9,809
ALASKA	2,232	23	2,209
ARIZONA	12,068	3,382	8,686
ARKANSAS	15	15	--
CALIFORNIA	1,763,749	1,701,271	62,478
COLORADO	134,821	127,664	7,157
CONNECTICUT	39,793	38,789	1,004
DELAWARE	871	221	650
DIST COLUMBIA	31,152	22,449	8,703
FLORIDA	695,843	691,874	3,969
GEORGIA	5,953	3,944	2,009
HAWAII	2,087	228	1,859
IDAHO	0	--	--
ILLINOIS	11,541	8,007	3,534
INDIANA	8,210	5,854	2,356
IOWA	2,896	159	2,737
KANSAS	3,349	2,789	560
KENTUCKY	1,433	1,086	347
LOUISIANA	186,579	186,271	308
MAINE	249	30	219
MARYLAND	372,265	347,274	24,991
MASSACHUSETTS	42,823	12,448	30,375
MICHIGAN	8,451	3,122	5,329
MINNESOTA	3,249	1,868	1,381
MISSISSIPPI	47,081	46,160	921
MISSOURI	11,147	10,131	1,016
MONTANA	241	192	49
NEBRASKA	386	--	386
NEVADA	224	224	--
NEW HAMPSHIRE	4,385	1,643	2,742
NEW JERSEY	62,693	60,556	2,137
NEW MEXICO	22,588	20,602	1,986
NEW YORK	33,183	22,457	10,726
NORTH CAROLINA	4,820	1,478	3,342
NORTH DAKOTA	62	--	62
OHIO	107,357	93,039	14,318
OKLAHOMA	1,468	471	997
OREGON	2,613	1,093	1,520
PENNSYLVANIA	140,289	134,965	5,324
RHODE ISLAND	912	275	637
SOUTH CAROLINA	392	--	392
SOUTH DAKOTA	240	(3)	243
TENNESSEE	14,722	11,157	3,565
TEXAS	559,742	525,102	34,640
UTAH	330,551	329,874	677
VERMONT	132	91	41
VIRGINIA	178,647	159,628	19,019
WASHINGTON	34,370	31,715	2,655
WEST VIRGINIA	1,297	50	1,247
WISCONSIN	19,366	12,584	6,782
WYOMING	160	--	160

Note: Excludes smaller procurements, generally those of $25,000 or less; also excludes awards placed through other Government agencies, awards outside the U.S., and actions on the JPL contracts.

IX. AWARDS PLACED OUTSIDE THE UNITED STATES

During the first six months of Fiscal Year 1990, NASA placed $45.2 million in awards that are being performed outside the United States.

As indicated in the following tabulation, $45,166 thousand represented direct NASA awards; $30 thousand constituted awards place through other Government agencies. The awards are being performed in eleven different countries and two U.S. territories.

PLACE OF PERFORMANCE	(THOUSANDS)
TOTAL	$45,196*
DIRECT NASA AWARDS	$45,166
AUSTRALIA	9,118
BERMUDA	337
CANADA	18,440
CHILE	551
ISRAEL	71
JAPAN	394
NETHERLANDS	71
PUERTO RICO	100
ST. HELENA	155
SPAIN	14,187
UNITED KINGDOM	910
WEST GERMANY	832
PLACED THROUGH OTHER GOVERNMENT AGENCIES	$30
GUAM	30

*EXCLUDES SMALLER PROCUREMENTS, GENERALLY THOSE OF LESS THAN $25,000.

THE PRIVATE SECTOR ECONOMIC AND EMPLOYMENT BENEFITS TO THE NATION AND TO EACH STATE OF PROPOSED FY 1990 NASA PROCUREMENT EXPENDITURES

Prepared For

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April 1989

TABLE OF CONTENTS

Page

EXECUTIVE SUMMARY.....i

LIST OF TABLES.....xi

LIST OF FIGURES.....xiii

PREFACE.....xiv

I. INTRODUCTION.....1

II. TRADITIONAL ECONOMIC RATIONALE FOR THE SPACE PROGRAM.....2

III. THE DIRECT AND INDIRECT ECONOMIC AND EMPLOYMENT BENEFITS OF EXPENDITURES ON THE SPACE PROGRAM.....4

IV. THE MISI APPROACH.....5

V. BENEFITS AT THE NATIONAL LEVEL.....11

VI. THE BENEFITS TO EACH STATE.....30

BIBLIOGRAPHY.....48

EXECUTIVE SUMMARY

This report estimates the private sector economic and employment benefits (disaggregated among 80 industries and 475 occupations) of proposed FY 1990 NASA procurement expenditures to the nation and to each state. Nationwide, it finds that FY 1990 NASA procurement expenditures of $11.3 billion will have an economic multiplier of 2.1 and will create, directly and indirectly:

- 237,000 jobs*
- $23.2 billion in total industry sales
- $2.4 billion in corporate profits
- $7.4 billion in Federal, state, and local government tax revenues

These benefits are widely dispersed throughout the United States and are significant in many states not normally considered to be major beneficiaries of NASA spending (Figure EX.1).

This study (the first comprehensive analysis of the state-by-state industry and job effects of NASA procurement spending) finds that the industries benefiting the most from NASA procurement include many in the basic manufacturing and the high technology areas. Examining the indirect effects of NASA procurement emphasizes that NASA spending supports such basic industries as Iron and Steel Manufacturing, Metalworking Machinery, and Chemicals (Table EX.1).

Table EX.1 illustrates (for select industries) the indirect economic multipliers resulting from proposed FY 1990 NASA procurement expenditures. For each industry these multipliers show the ratio of total to direct output requirements resulting from NASA procurement spending. The larger the multiplier, the greater are the indirect requirements for the output of the industry generated by NASA procurement. The multipliers are seen to vary widely among individual industries, ranging from a high of 42 for Iron and Steel Manufacturing to a low of 1.2 for Aircraft and Parts.

The jobs created (Table EX.2) are disproportionately concentrated among Scientists, Engineers, and skilled workers, and NASA procurement programs are thus a significant factor in

*These are jobs in private industry and do not include NASA employees or other Federal workers.

Figure EX.1

States Benefiting Most from U.S. Space Program
Fiscal Year 1990

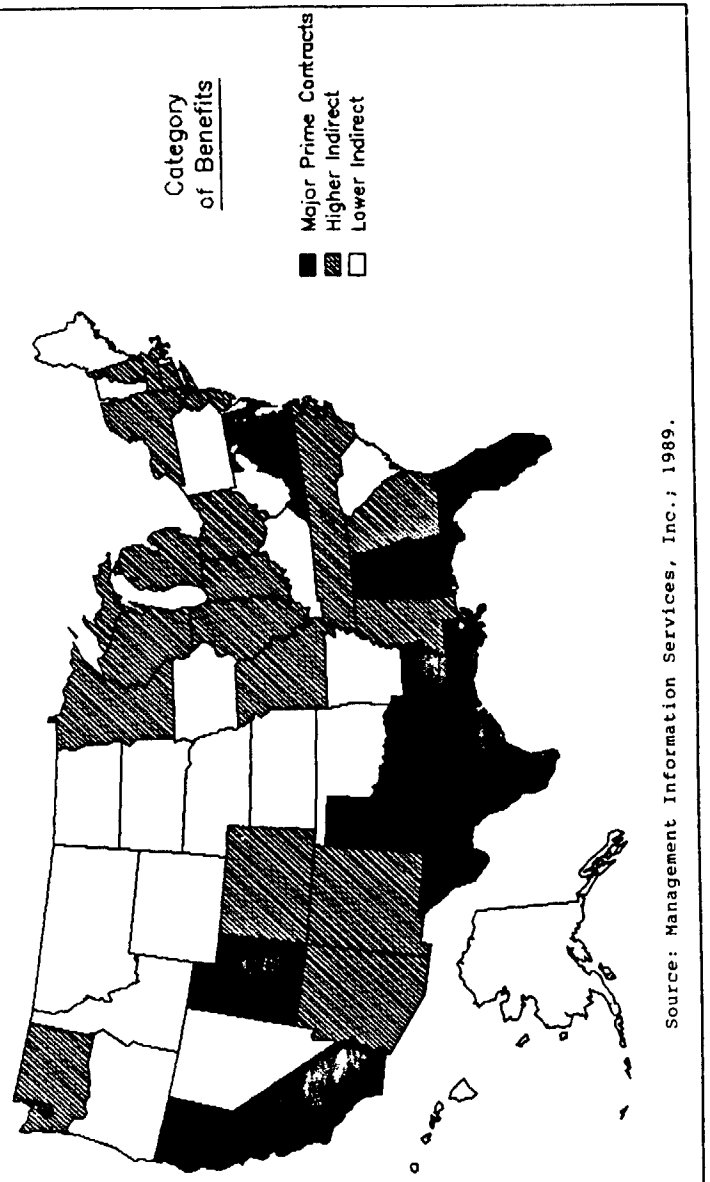


Table EX.1

Indirect Economic Multipliers Resulting from Proposed NASA FY 1990 Procurement Expenditures -- Selected Industries

Industry	Multiplier[a]
Primary Iron and Steel Manufacturing	41.8
Primary Nonferrours Metals Manufacturing	30.0
Electric Lighting and Wiring Equipment	13.5
Rubber and Misc. Plastics Products	8.3
Metalworking Machinery	8.1
Electronic Components	6.7
Misc. Fabricated Metal Products	5.9
Electric, Gas, and Sanitary Services	4.5
Chemicals and Selected Chemical Products	3.2
Metal Containers	3.2
Wholesale and Retail Trade	3.0
Communications, except Radio and Television	2.4
Business Services	2.4
Electrical Transmission Equipment	2.3
Transportation and Warehousing	2.2
Electrical Transmission Equipment	2.3
Transportation and Warehousing	2.2
AVERAGE, ALL INDUSTRIES	2.1
Motor Vehicles and Equipment	2.0
Optical, Ophthalmic, and Photgraphic Equipment and Supplies	1.8
Petroleum Refining and Related Industries	1.8
Office, Computing, and Accounting Machines	1.7
Engines and Turbines	1.4
Aircraft and Parts	1.2
Miscellaneous Transportation Equipment	1.1

[a]Ratio of total to direct output requirements.

Source: Management Information Services, Inc., 1989.

Table EX.2

Jobs Created by Proposed FY 1990 NASA Procurement Expenditures Within Selected Occupations, Ranked by Relative Job Impact

Rank[a]		Jobs Created
1	Aerospace Engineers	3,441
2	Mechanical Engineering Technicians	577
3	Electronic Repairers, Communications Equipment	915
4	Inspectors and Testors	1,556
5	Aircraft Engine Mechanics	881
6	Electrical Engineers	5,304
7	Mathematicians	123
8	Electrical Equipment Asseblers	2,047
9	Solderers and Brazers	395
10	Metallurgical Engineers	344
11	Industrial Engineers	2,288
12	Operations and Systems Researchers	1,359
13	Electrical Technicians	2,404
14	Mechanical Engineers	2,413
15	Grinding and Polishing Machine Operators	1,266
16	Metal Plating Machine Operators	394
17	Tool and Die Makers	1,272
18	Misc. Engineering Technicians	1,653
19	Computer Programmers	2,736
20	Marine Engineers	98
21	Purchasing Agents and Buyers	1,472
22	Technical Writers	329
23	Chemical Engineers	476
24	Computer Systems Analysts	1,620
25	Misc. Engineers	986
26	Misc. Science Technicians	344
27	Drafting Occupations	1,174
28	Civil Engineers	897
29	Mining Engineers	52
30	Chemists, except Biochemists	412

[a]Ranked on the basis of the percent job impact on the occupation.

Source: Management Information Services, Inc., 1989

the labor market for many Science, Engineering, and skilled occupations. Nevertheless, the study determines that NASA expenditures create (in absolute terms) many more jobs for blue collar and lesser skilled labor not normally linked to the Space Program. Substantial numbers of jobs are created in virtually every industry and every occupation.

The total sales and jobs created in each state by proposed FY 1990 NASA procurement expenditures are estimated (Table EX.3). As expected, significant industry and job benefits accrue to those states such as California, Texas, and Florida that are the largest direct recipients of NASA procurement funds. However, as Table EX.3 shows, all states benefit economically from the Space Program and significant benefits accrue to states other than those receiving the prime contract awards.

A major purpose of the analysis is to identify the indirect economic benefits to each state resulting from the U.S. Space program -- the benefits flowing from the second- third- and fourth rounds of industry purchases generated by NASA procurement expenditures. For some states these are found to be very high, with multipliers of total to direct benefits of 10 to 1 and higher (Table EX.4 and Figure EX.2).

Each state is ranked on the basis of several criteria, including the total benefits, indirect benefits, and per capita benefits received from NASA spending. These criteria permit the identification of the states benefitting the most, both directly and indirectly, from proposed FY 1990 NASA procurement (Figure EX.1).

The states receiving the most benefits directly, the major prime contractor award states, are (Figure EX.1): Alabama, California, Florida, Louisiana, Maryland, Texas, Utah, and Virginia.

The states receiving the most benefits indirectly (Figure EX.1) are: Arizona, Colorado, Connecticut, Georgia, Illinois, Indiana, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Tennessee, Washington, and Wisconsin.

The report thus finds that while high prime contract award states such as California, Texas, and Florida benefit greatly from NASA procurement spending, so also do other states such as Michigan, which receive only a relatively small portion of NASA contracts. As shown in Figure EX.1, these "winners" include many states not usually linked to the Space Program, such as New Jersey, Arizona, Minnesota, Illinois, Tennessee, Wisconsin, Michigan, New Hampshire, and North Carolina.

For example, proposed FY 1990 NASA procurement spending will create (directly and indirectly) 5,700 jobs and $550 million in

Table EX.3

Estimated Sales and Jobs Created in Each State by Proposed FY 1990 NASA Procurement Expenditures

State	Sales (millions)	(% of US)	Employment (number)	(% of US)
Alabama	$858.2	3.7	8,582	3.6
Alaska	35.5	0.2	236	0.1
Arizona	229.6	1.0	2,424	1.0
Arkansas	89.0	0.4	876	0.4
California	6,766.6	29.2	70,332	29.7
Colorado	490.3	2.1	5,381	2.3
Connecticut	601.1	2.6	6,224	2.6
Delaware	32.7	0.1	291	0.1
Dist. Columbia	75.2	0.3	990	0.4
Florida	1,297.5	5.6	14,756	6.2
Georgia	299.7	1.3	3,224	1.4
Hawaii	23.0	0.1	278	0.1
Idaho	21.4	0.1	242	0.1
Illinois	549.2	2.4	5,657	2.4
Indiana	348.3	1.5	3,253	1.4
Iowa	94.7	0.4	1,050	0.4
Kansas	172.0	0.7	1,697	0.7
Kentucky	142.4	0.6	1,358	0.6
Louisiana	535.0	2.3	4,583	1.9
Maine	36.0	0.2	386	0.2
Maryland	994.3	4.3	11,122	4.7
Massachusetts	382.3	1.7	4,208	1.8
Michigan	518.9	2.2	4,582	1.9
Minnesota	164.3	0.7	1,791	0.8
Mississippi	231.9	1.0	2,146	0.9
Missouri	342.3	1.5	3,427	1.4
Montana	18.7	0.1	180	0.1
Nebraska	47.7	0.2	566	0.2
Nevada	30.2	0.1	379	0.2
New Hampshire	58.7	0.3	626	0.3

Table EX.3 (continued)

Estimated Sales and Jobs Created in Each State by Proposed FY 1990 NASA Procurement Expenditures

State	Sales (millions)	(% of US)	Employment (number)	(% of US)
New Jersey	506.0	2.2	5,411	2.3
New Mexico	135.5	0.6	1,242	0.5
New York	711.1	3.1	7,820	3.3
North Carolina	231.3	1.0	2,450	1.0
North Dakota	18.0	0.1	183	0.1
Ohio	928.7	4.0	8,545	3.6
Oklahoma	158.7	0.7	1,358	0.6
Oregon	67.3	0.3	731	0.3
Pennsylvania	602.2	2.6	5,955	2.5
Rhode Island	32.3	0.1	347	0.1
South Carolina	109.5	0.5	1,139	0.5
South Dakota	18.3	0.1	221	0.1
Tennessee	209.1	0.9	2,237	0.9
Texas	2,105.4	9.1	19,528	8.3
Utah	590.8	2.6	5,895	2.5
Vermont	21.1	0.1	226	0.1
Virginia	631.2	2.7	6,666	2.8
Washington	308.4	1.3	3,173	1.3
West Virginia	61.0	0.3	502	0.2
Wisconsin	193.0	0.8	1,991	0.8
Wyoming	28.0	0.1	210	0.1
Total	$23,153.2	-	236,679	-

Source: Management Information Services, Inc.; 1989.

Table EX.4

Economic Multipliers for Selected States Resulting From Proposed FY 1990 NASA Procurement Expenditures

	Multiplier[a]
Michigan	14.0 to 1
Indiana	12.0 to 1
Illinois	9.8 to 1
Missouri	8.3 to 1
Oregon	6.7 to 1
North Carolina	5.6 to 1
Georgia	5.5 to 1
Wisconsin	5.2 to 1
Tennessee	5.1 to 1
New York	4.6 to 1
Pennsylvania	4.0 to 1
Kansas	3.8 to 1
Ohio	3.8 to 1
Massachusetts	2.7 to 1
Mississippi	2.1 to 1
Arizona	2.0 to 1
New Jersey	2.0 to 1
Texas	1.8 to 1
California	1.8 to 1
Alabama	1.4 to 1
Florida	1.1 to 1

[a]Ratio of total (direct plus indirect) economic benefits to direct economic benefits.

Source: Management Information Services, Inc., 1989.

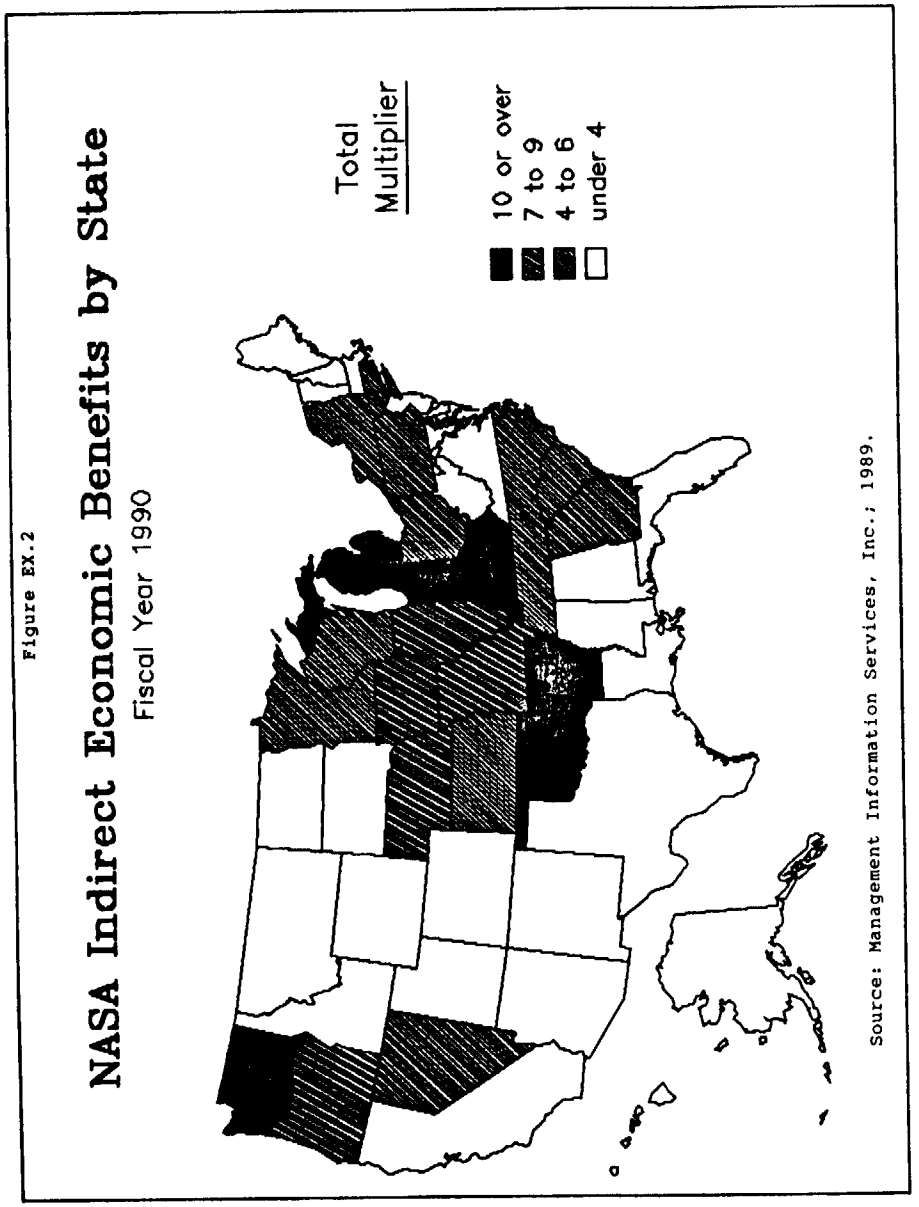


Figure EX.2

industry sales in Illinois. Further, for every direct dollar of NASA spending in this state, an additional 10 dollars of spending will be generated indirectly by the NASA procurement budget.

This may seem counterintuative, since Illinois is not generally considered to be a state that benefits greatly from the Space Program. However, Illinois benefits substantially from NASA spending. Its industries produce the goods and services required indirectly by the recipients of NASA procurement awards: capital goods, electronic components, scientific instruments, chemical products, primary and fabricated metal products, specialized business services, etc. Further, because of the widely based, indirect nature of these economic benefits to the state, Illinois will benefit greatly from NASA procurement spending in other states on a wide variety of programs, and its benefits are not tied to a specific contract, project, or program. In this sense, a state like Illinois is a more certain beneficiary of NASA spending than are some states receiving sizable prime contract awards.

The implications of these results are discussed.

The major conclusions of this study are:

- The detailed economic and job benefits of the U.S. Space Program can be reliably estimated by industry and occupation for the nation and for each state.
- The total (direct plus indirect) economic and employment benefits are between two and three times larger than is usually assumed, and are much more pervasive than is generally recognized.
- The major beneficiaries -- specific industries, occupations, and states -- include many which have heretofore not been linked closely to the Space Program or to NASA procurement.
- NASA spending plays a key role in supporting U.S. basic manufacturing and high technology industries.
- NASA procurement expenditures have a disproportionately large impact on the labor markets for Scientists, Engineers, and skilled workers.
- The estimates developed here are important for maintaining a viable U.S. Space Program through the remainder of this century.

LIST OF TABLES

Page

EX.1 Indirect Economic Multipliers Resulting from Proposed FY 1990 NASA Procurement--Selected Industries.....iii

EX.2 Jobs Created by Proposed FY 1990 NASA Procurement Expenditures Within Selected Occupations, Ranked by Relative Job Impact.....iv

EX.3 Estimated Sales and Jobs Created in Each State by Proposed FY 1990 NASA Procurement Expenditures.....vi

EX.4 Economic Multipliers for Selected States Resulting From Proposed FY 1990 NASA Procurement Expenditures.....viii

IV.1 80-Order U.S. Input-Output Industries.....8

V.1 Summary of NASA Procurement Awards, FY 1988.....12

V.2 Overview of the Economic Benefits of Proposed FY 1990 NASA Procurement Expenditures.....13

V.3 Impact of Proposed FY 1990 NASA Procurement Expenditures on Output by Industry.....14

V.4 Impact of Proposed FY 1990 NASA Procurement Expenditures, Ranked by Industry.....16

V.5 Impact of Proposed FY 1990 NASA Procurement Expenditures, Ranked by Relative Industry Size.....17

V.6 Indirect Economic Multipliers Resulting from Proposed FY 1990 NASA Procurement--Selected Industries.....19

V.7 Employment Created in Each Industry by Proposed FY 1990 NASA Procurement Expenditures.....21

V.8 Jobs Created by Proposed FY 1990 NASA Procurement Expenditures -- Major Occupational Groups.....23

V.9 Jobs Created by Proposed FY 1990 NASA Procurement Expenditures Within Selected Occupations.....24

V.10 Jobs Created by Proposed FY 1990 NASA Procurement Expenditures Within Selected Occupations, Ranked by Relative Job Impact.....28

VI.1 Estimated FY 1990 NASA Procurement Awards by Type of Contractor and by State.....31

VI.2 Estimated FY 1990 NASA Procurement Awards by Type of Contractor and by State (Percent Distribution).....33

VI.3 Estimated Sales and Jobs Created in Each State by Proposed FY 1990 NASA Procurement Expenditures.....36

VI.4 Ranking of the Top 20 States on the Basis of Total Industry Sales Generated by Proposed FY 1990 NASA Procurement Expenditures.....38

VI.5 Ranking of the Top 20 States on the Basis of Jobs Created Per Capita by Proposed FY 1990 NASA Procurement Expenditures.....39

VI.6 Ranking of the Top 20 States on the Basis of Industry Sales Generated Indirectly by Proposed FY 1990 NASA Procurement Expenditures.....40

VI.7 Economic Multipliers for Selected States Resulting From Proposed FY 1990 NASA Procurement Expenditures.....43

VI.8 Categorization of the States Benefiting Most From Proposed FY 1990 NASA Procurement Expenditures.....46

Appendix: Detailed Occupational Jobs Created by Proposed FY 1990 NASA Procurement Expenditures.....52

LIST OF FIGURES

Page

EX.1 States Benefiting Most From U.S. Space Program, Fiscal Year 1990.....ii

EX.2 NASA Indirect Economic Benefits by State, Fiscal Year 1990.....ix

IV.1 Estimating the Economic and Employment Effects of the U.S. Space Program.....6

IV.2 MISI National and Regional Analysis of the Impacts of NASA Procurements.....7

VI.1 NASA Prime Contract Awards, FY 1990, by State as a Percent of the U.S. Total.....35

VI.2 NASA Indirect Economic Benefits by State, Fiscal Year 1990.....44

VI.3 States Benefiting Most From U.S. Space Program, Fiscal Year 1990.....47

PREFACE

This study was undertaken by Management Information Services, Inc. for the NASA Alumni League to determine the effects which the proposed NASA procurement budget for Fiscal Year 1990 will likely have on the nation's economy and on the economies of each state. An earlier study by MISI for the NAL analyzed the impact of FY 1987 NASA procurement expenditures.

I. INTRODUCTION

The long run economic benefits of the U.S. Space Program have been identified over the past three decades. These include spin-offs, support of research and development, creation of public goods, and the development of new space industries. However, the immediate, near term benefits to the nation's economy of NASA expenditures have not been estimated. This is unfortunate, since NASA, like every major Federal agency, should have some idea of the likely impact of its programs on the economy, on specific industries and labor markets, and on regions and states. Such economic impact information would be useful in assessing the effects of agency budgets and could assist in program planning.

Thus, an important question that must be addressed is the impact that NASA spending is likely to have on a particular state, industry, or labor market.

The MISI analysis presented here answers the question by showing the direct and indirect economic benefits of proposed FY 1990 NASA procurement expenditures to the nation and to each state. Specifically, the analysis shows:

- The total economic benefits to the private sector -- increase in economic product -- likely to accrue to the nation and to each state from the proposed FY 1990 NASA procurement budget.
- The jobs and industry sales likely to be created in each state by the procurement program.
- The jobs created within each of 475 occupations by NASA procurement expenditures.
- The total Federal, state, and local government tax revenues generated the NASA programs.
- The direct and the indirect sales created within each industry.
- The multiplier effect which NASA procurement has on the economy of each state.
- The impact on key industries, occupations, and R&D sectors of spending on NASA programs.

This type of analysis, while based on well established and validated economic methodology, has never before been applied to the U.S. Space Program or to the NASA budget. Given the intense current debate over the future of the civilian Space Program, the analysis is long overdue.

II. TRADITIONAL ECONOMIC RATIONALE FOR THE SPACE PROGRAM

Over the years advocates of the Space Program have identified several types of economic benefits of the U.S. Space Program:

- public goods.
- spin-offs.
- R & D support.
- creation of new space industries.

Public Goods

Public goods are commodities which only the government can provid in sufficient quantity, since their benefits cannot be captured by private investors in the form of profit, and they remain underproduced unless the government intervenes. For the Space Program these include knowledge gained about the universe and it's origins, information on the characteristics and the history of the earth and solar system, and related basic scientific knowledge.

Spin-offs

Spin-offs are those technologically advanced products and processes developed for the Space Program which ultimately find productive uses in other areas--areas often unrelated to space exploration. These include photovoltaics, advances in aerodynamic design, enhanced telecommunications systems, breakthroughs in microelectronics, improved chemical processes, and so forth.

Research and Development Support

The Space Program enhances the nation's technology base and that of specific industries, and Program advocates argue that it is vital to the technological competitiveness of U.S. industry. Studies have shown that investments in NASA R & D have a return of between five and ten to one over a 25 year horizon, and few doubt the importance of R & D programs for the U.S. economy.

Creation of New Space-Based Industries

Advocates of ambitious space programs emphasize the potential for creating new space-based industries, including private launch services, materials processing in space and related applications of a microgravity environment, remote imaging, infrastructure development, and so forth. Obviously, without a strong U.S. government Space Program, development of these new industries will be delayed and

opportunities lost to other nations.

The analysis developed by MISI for NAL provides another measure of the economic effects of the Space Program, for it identifies the specific industries, regions, and jobs benefiting the most from NASA procurement expenditures. It thus provides findings necessary for assessing the economic viability of the U.S. Space Program during the 1990s.

III. THE DIRECT AND INDIRECT ECONOMIC AND EMPLOYMENT BENEFITS OF EXPENDITURES ON THE SPACE PROGRAM

Here we estimate the following benefits of proposed FY 1990 NASA procurement expenditures:

- o direct and indirect
- o economic
- o employment
- o national
- o state-specific

Direct and Indirect

The benefits estimated here include those resulting from the initial procurement expenditures as well as those generated indirectly throughout the economy by the expenditures. Where appropriate, the multipliers (ratio of total benefits to direct benefits) are computed.

Economic

The benefits to each of 80 all-inclusive two-digit SIC industries are estimated. The benefits are the increased output, sales, and profits generated by the Space Program expenditures.

Employment

The total number of jobs created in each of the 80 industries and in each of 475 all-inclusive occupations is estimated. The job data pertain to full-time equivalent (FTE) person-years.

National

Output, sales, profits, and employment are estimated for each industry at the national level, and for each occupation the total number of jobs created nationwide is derived.

State-specific

Output, sales, profits, and employment are estimated for each industry at the state level, for each occupation the total number of jobs created within every state is derived, and the tax revenues generated in the state are computed.

IV. THE MISI APPROACH: ESTIMATING THE TOTAL (DIRECT PLUS INDIRECT) EFFECTS

The economic and employment effects of proposed FY 1990 NASA procurement expenditures were computed using the Management Information Services, Inc. data base and information system. A simplified version of the MISI model is illustrated in Figure IV.1, and the specification of the NASA budget simulations is shown in Figure IV.2.

The basis of the model used here is economic input-output analysis. This analytical methodology was developed by Wassily Leontief (for which he was awarded the Nobel Prize in Economics), and it has been widely used and validated over the past five decades by economists in many nations.

The first step is the translation of expenditures for a program or set of programs into per unit output requirements from every industry in the economy. This is determined by four major factors: 1) the state of technology, 2) the distribution of expenditures, 3) the specific program configuration, and 4) the direct industry requirements structure. While the model contains 500 industries, in the work conducted here an 80-order industry scheme was used -- see Table IV.1.

Second, the direct output requirements of every industry affected as a result of expenditures on the program are estimated. These direct requirements show, proportionately, how much an industry must purchase from every other industry to produce one unit of output.

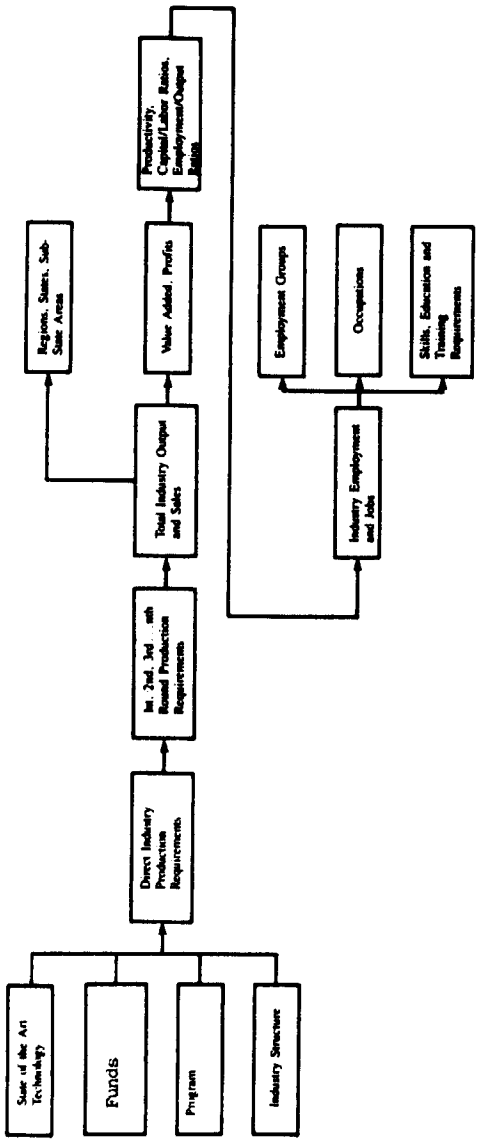
Direct requirements, however, give rise to subsequent rounds of indirect requirements. For example, steel mills require electricity to produce steel. But an electric utility requires turbines from a factory to produce electricity. The factory requires steel from steel mills to produce turbines, and the steel mill requires more electricity, . . ., and so on.

The latter are the indirect requirements. The sum of the direct plus the indirect requirements represents the total output requirements from an industry necessary to produce one unit of output. Economic input-output (I-O) techniques allow us to compute the direct as well as the indirect production requirements, and these total requirements are represented by the "inverse" equations in the model. The ratio of the total requirements to the direct requirements is called the input-output multiplier.

Thus, in the third step in the model the direct industry output requirements are converted into total output requirements from every industry by means of the input-output inverse equations. These equations show not only the direct requirements, but also the second, third, fourth, . . ., nth round indirect industry and service sector requirements resulting from expenditures on the Space program.

Figure IV.1

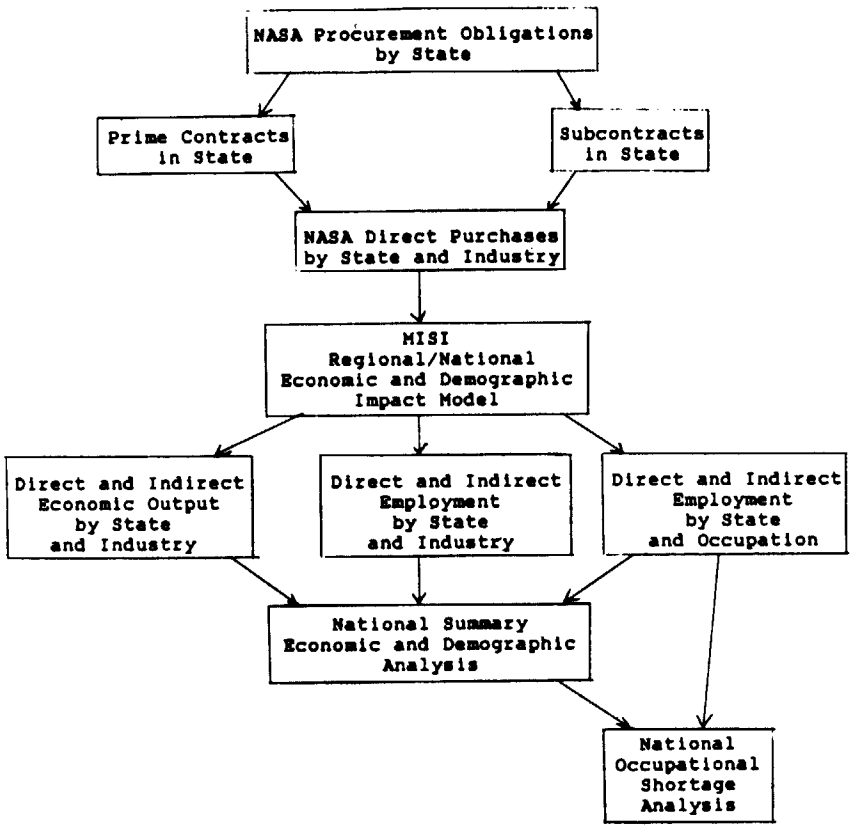
Estimating the Economic and Employment Effects of the U.S. Space Program



Source: Management Information Services, Inc., 1989

Figure IV.2

MISI National and Regional Analysis of the Impacts of NASA Procurements


NASA Procurement Obligations by State
Prime Contracts in State
Subcontracts in State
NASA Direct Purchases by State and Industry
MISI Regional/National Economic and Demographic Impact Model
Direct and Indirect Economic Output by State and Industry
Direct and Indirect Employment by State and Industry
Direct and Indirect Employment by State and Occupation
National Summary Economic and Demographic Analysis
National Occupational Shortage Analysis

Source: Management Information Services, Inc., 1989

Table IV.1

80-Order U.S. Input-Output Industries

Industry number and title	Related Census-SIC codes (1972 edition)
AGRICULTURE, FORESTRY, AND FISHERIES	
1. Livestock and livestock products	pt. 01, pt. 02
2. Other agricultural products	pt. 01, pt. 02
3. Forestry and fishery products	0811-4, 081, 097
4. Agricultural, forestry, and fishery services	0724, 07 (excl. 074), 085, 092
MINING	
5. Iron and ferroalloy ore mining	101, 106
6. Nonferrous metal ore mining	102-5, pt. 109, 108
7. Coal mining	1111, pt. 1112, 1211, pt. 1213
8. Crude petroleum and natural gas	131, 132, pt. 138
9. Stone and clay mining and quarrying	141-5, pt. 148, 149
10. Chemical and fertilizer mineral mining	147
CONSTRUCTION	
11. New construction	pt. 15-17, pt. 109, pt. 1112, pt. 1212, pt. 148
12. Maintenance and repair construction	pt. 15-17, pt. 138
MANUFACTURING	
13. Ordnance and accessories	3482-4, 3489, 3761, 3795
14. Food and kindred products	20
15. Tobacco manufactures	21
16. Broad and narrow fabrics, yarn and thread mills	221-4, 226, 228
17. Miscellaneous textile goods and floor coverings	227, 229
18. Apparel	225
19. Miscellaneous fabricated textile products	239
20. Lumber and wood products, except containers	241-3, 2donn, 249
21. Wood containers	2441, 2449
22. Household furniture	251
23. Other furniture and fixtures	252-6, 259
24. Paper and allied products, except containers and boxes	261-4, 266
25. Paperboard containers and boxes	265
26. Printing and publishing	27
27. Chemicals and selected chemical products	281, 285-7, 289
28. Plastics and synthetic materials	282
29. Drugs, cleaning and toilet preparations	283-4
30. Paints and allied products	285
31. Petroleum refining and related industries	29
32. Rubber and miscellaneous plastics products	30
33. Leather tanning and finishing	311
34. Footwear and other leather products	313-7, 319
35. Glass and glass products	321-3
36. Stone and clay products	324-9
37. Primary iron and steel manufacturing	331-2, 339, 3462
38. Primary nonferrous metals manufacturing	333-6, 3463
39. Metal containers	341
40. Heating, plumbing, and fabricated structural metal products	343-4
41. Screw machine products and stampings	345, 3466-8, 3469
42. Other fabricated metal products	342, 347, 349
43. Engines and turbines	351
44. Farm and garden machinery	352
45. Construction and mining machinery	3531-3
46. Materials handling machinery and equipment	3536-7
47. Metalworking machinery and equipment	354
48. Special industry machinery and equipment	355
49. General industrial machinery and equipment	356
50. Miscellaneous machinery, except electrical	359
51. Office, computing, and accounting machines	357
52. Service industry machines	358
53. Electrical transmission and distribution equipment and industrial apparatus	361-3, 3625
54. Household appliances	363
55. Electric lighting and wiring equipment	364
56. Radio, TV, and communication equipment	365-6
57. Electronic components and accessories	367
58. Miscellaneous electrical machinery, equipment, and supplies	369
59. Motor vehicles and equipment	371
60. Aircraft and parts	372
61. Other transportation equipment	373-5, 3792, 3799, 3discl
62. Professional, scientific, and controlling instruments and supplies	381, 3822-9, 3829, 384, 387
63. Optical, ophthalmic, and photographic equipment and supplies	383, 385-6
64. Miscellaneous manufacturing	39
TRANSPORTATION, COMMUNICATION, AND UTILITIES	
65. Transportation and warehousing	40-2, 44-7
66. Communications, except radio and TV	481-2, 489
67. Radio and TV broadcasting	483
68. Electric, gas, water, and sanitary services	49
WHOLESALE AND RETAIL TRADE	
69. Wholesale and retail trade	50-57, 59, 7396, 5963
FINANCE, INSURANCE, AND REAL ESTATE	
70. Finance and insurance	60-64, 67
71. Real estate and rental	65-6, pt. 1531
SERVICES	
72. Hotels and lodging, personal and repair services (except auto)	70-7, 763-4, pt. 7699
73. Business services	73 (excl. 7396), 7697, 7699, pt. 7699
74. Eating and drinking places	58
75. Automobile repair and services	75
76. Amusements	78-9
77. Health, educational, and social services and nonprofit organizations	076, 80 (excl. 8042), 82-84, 86, 8922
GOVERNMENT ENTERPRISES	
78. Federal Government enterprises	not applicable
79. State and local government enterprises	not applicable
DUMMY AND SPECIAL INDUSTRIES	
80. Noncomparable imports	
81. Scrap, used, and secondhand goods	
82. Government industry	
83. Rest of the world industry	
84. Household industry	
85. Inventory valuation adjustment	
FINAL DEMAND	
91. Personal consumption expenditures	
92. Gross private domestic fixed investment	
93. Change in business inventories	
94. Exports	
95. Imports	
96. Federal Government purchases, national defense	
97. Federal Government purchases, nondefense	
98. State and local government purchases, education	
99. State and local government purchases, other	

Source: U.S. Department of Commerce, Bureau of Economic Analysis

Next, the total output requirements from each industry are used to compute sales volumes, profits, and value added for each industry. Then, using data on manhours, labor requirements, and productivity, employment requirements within each industry are estimated. This allows computation of the total number of jobs created within each industry.

The next step requires the conversion of total employment requirements by industry into job requirements for specific occupations and skills. To accomplish this, MISI utilizes data on the occupational composition of the labor force within each industry and estimates job requirements for 475 specific occupations encompassing the entire U.S. labor force. This permits estimation of the impact of the program on jobs for specific occupations and on skills, education, and training requirements.

Utilizing the modeling approach outlined above, MISI estimated the effects on employment, personal income, corporate sales and profits, and government tax revenues in the United States and in each state. Estimates were then developed for detailed industries and occupations. The results of this analysis serve as the baseline and represent comprehensive and detailed estimates of the national and statewide economic benefits of expenditures on the U.S. Space program.

The next step in the analysis (not conducted here) is to assess the economic impact on specific cities and Metroplitan Statistical Areas (MSAs). The MISI approach permits disaggregation to the level of most U.S. MSAs and, if desired, to the county level.

Empirically, the basis of the sub-state estimates is the Regional Input-Output Modeling System (RIMS II) developed by the U.S. Commerce Department's Bureau of Economic Analysis (BEA) over the past two decades.

RIMS II is based on economic input-output analysis which shows, for each industry, industrial distributions of inputs purchased and outputs sold. A typical input-output table in RIMS II is constructed primarily from two sources: 1) BEA's national I-O table, which shows the input and the output structures of more than 500 U.S. industries, and 2) BEA's four-digit Standard Industrial Classification (SIC) county wage-and-salary data, which were used to adjust the national I-O table to show the Rochester MSA's industrial structure and trading patterns.

The main data sources for RIMS II permit economic impacts to be estimated for any region composed of one or more counties and for any industry in the national I-O table. RIMS II can be used to estimate the impacts of project and program expenditures by industry on regional output (gross receipts or sales), earnings (the sum of wages and salaries, proprietors' income, and other labor income, less employer contributions to private pension and welfare funds), and employment. The use of the RIMS II methodology has been validated in independent studies over the past two decades.

For MSAs the MISI model permits estimation of the impact on requirements for specific occupations. To accomplish this it utilizes the MISI occupation-by-industry matrix, the coefficients of which show the percent distribution of occupational employment among all industries. The 80-by-475 matrix was developed from the 1983 Current Population Survey, updated by MISI to 1990, and is aggregated to 39 industries to conform to the RIMS II industry aggregation.

The MISI model was developed using publicly available data from the U.S. Department of Commerce and the U.S. Department of Labor. The data on proposed NASA procurement expenditures used in the study are publicly available from the National Aeronautics and Space Administration.

V. BENEFITS AT THE NATIONAL LEVEL

We first wish to determine the total (direct plus indirect) economic and employment impact at the national level of proposed FY 1990 NASA procurement expenditures. We simulated the effects of the proposed FY 1990 NASA procurement awards ($11.3 billion--see Table V.1) on sales, earnings, profits, and employment within 80 all-inclusive industries.

These impacts at the national level are summarized in Table V.2. This table shows that in 1990 NASA procurement of $11.3 billion is estimated to:

- o generate $23.2 billion in total industry sales.
- o have a multiplier effect on the economy of 2.1.
- o create 237,000 jobs.
- o create $2.4 billion in total industry profits.
- o generate $7.4 billion in Federal, state, and local government tax revenues.

The total sales generated within each industry are shown in Table V.3, and these industries are ranked in Table V.4. As expected, the largest total impacts of NASA procurement are concentrated in Aircraft and Parts, Ordnance and Accessories, Radio, T.V., and Communications Equipment, and related industries.

The rankings in Table V.4 show the total impact on each industry's output of NASA FY 1990 procurement spending and are useful in determining where the largest dollar impacts will be. However, the size of these industries differs greatly: The output of the Business Services industry ($551 billion) is 17 times that of the Ordnance and Accessories industry ($32 billion); the output of the Transportation and Warehousing industry ($337 billion) is 6 times that of the Electronic Components industry ($58 billion). Thus a somewhat more meaningful measure of the relative importance of NASA procurement for each industry is the total output requirements of that industry generated by NASA procurement as a percent of the total industry output. These rankings of relative impacts are given in Table V.5.

This table shows that, in relative terms (based on industry size), NASA procurement spending impacts a somewhat different profile of industries than indicated in Table V.5. Some industries for which NASA procurement generates small amounts of output requirements, such as Wooden Containers ($5 million), Iron Ore Mining ($23 million), and Misc. Fabricated Metal Products ($98 million), are nevertheless greatly affected because of their relatively small size. In fact, based on percent impact, the Wooden Container industry is one of the main beneficiaries of NASA expenditures.

Table V.1

Summary of NASA Procurement Awards, FY 1988

	Amount (millions)	Percent	
Total	$9,545.1	100	-
Business Firms	7,274.9	76	100
Rockwell International Corp. Downey, CA	1,714.2	-	24
Lockheed Space Operations Co. Kennedy Space Center, FL	474.3	-	7
Morton Thiokol Inc. Brigham City, UT	422.8	-	6
Martin Marietta Corp. New Orleans, LA	341.0	-	5
McDonnell Douglas Corp. Huntington Beach, CA	299.1	-	4
Educational & Nonprofit	499.8	5	100
Stanford University Stanford, CA	27.7	-	6
Assn. Univ. Research & Astron. Baltimore, MD	23.7	-	5
New Mexico St. Univ.(Las Cruces) Palestine, TX	19.2	-	4
Universities Space Research Columbia, MD	17.0	-	3
Mass. Institute of Technology Cambridge, MA	14.3	-	3
Jet Propulsion Laboratory	979.9	10	100
Subcontracts	625.3	-	64
Other Government Agencies	734.6	8	100
Air Force	324.8	-	44
Treasury Department	176.7	-	24
Outside United States	55.9	1	

Source: NASA Annual Procurement Report, FY1988; MISI; 1989.

Table V.2
Overview of the Economic Benefits of Proposed
FY 1990 NASA Procurement Expenditures

Procurement Expenditures (millions)	$11,300
Total Sales Generated (millions)	$23,153
Economic Multiplier	2.1
Total Jobs Created	236,679
Total Profits Generated (millions)	$2,443
Total Federal, State, and Local Government Tax Revenues Generated (millions)	$7,431

Source: Management Information Services, Inc., 1989

Table V.3

Impact of Proposed FY 1990 NASA Procurement Expenditures on Output by Industry

Industry Title	Sales (millions)
Livestock & livestock products	$33.9
Other agricultural products	117.7
Forestry & fishery products	13.9
Agricultural, forestry & fishery services	20.7
Iron & ferroalloy ores mining	23.2
Nonferrous metal ores mining	41.3
Coal mining	86.0
Crude petroleum & natural gas	776.4
Stone & clay mining & quarrying	18.4
Chemical & fertilizer mineral mining	10.7
New construction	317.2
Maintenance & repair construction	679.3
Ordnance & accessories	2,438.1
Food & kindred products	107.1
Tobacco manufactures	0.1
Broad & narrow fabrics, yarn & thread mills	92.7
Miscellaneous textile goods & floor coverings	23.9
Apparel	62.3
Miscellaneous fabricated textile products	24.0
Lumber & wood products, exc. containers	125.8
Wood containers	4.8
Household furniture	14.6
Other furniture & fixtures	11.4
Paper & allied products	143.6
Paperboard containers & boxes	55.7
Printing & publishing	248.8
Chemicals & selected chemical products	376.9
Plastics & synthetic materials	131.7
Drugs, cleaning & toilet preparations	46.6
Paints & allied products	35.2
Petroleum refining & related industries	949.7
Rubber & miscellaneous plastics products	288.0
Leather tanning & finishing	1.8
Footwear & other leather products	4.8
Glass & glass products	36.3
Stone & clay products	119.2
Primary iron & steel manufacturing	512.0
Primary nonferrous metals manufacturing	671.4
Metal containers	19.0
Heating, fabricated metal products	186.5
Screw machine products & stampings	156.1
Other fabricated metal products	227.0

Table V.3 (continued)

Impact of Proposed FY 1990 NASA Procurement Expenditures on Output by Industry

Industry Title	Sales (millions)
Engines & turbines	152.2
Farm & garden machinery	9.8
Construction & mining machinery	40.3
Materials handling machinery	28.9
Metalworking machinery	98.1
Special industry machinery	19.2
General industrial machinery	156.1
Miscellaneous machinery, except electrical	184.2
Office, computing, & accounting machines	217.9
Service industry machines	35.6
Electrical transmission equipment	197.2
Household appliances	21.8
Electric lighting & wiring equipment	63.7
Radio, TV & communication equipment	1,392.6
Electronic components	722.1
Miscellaneous electrical machinery	50.1
Motor vehicles & equipment	354.7
Aircraft & parts	3,647.1
Other transportation equipment	490.2
Professional & scientific supplies	141.9
Optical & photographic equipment	136.6
Miscellaneous manufacturing	36.3
Transportation & warehousing	982.5
Communications, except radio & TV	257.9
Radio & TV broadcasting	49.4
Electric, gas, & sanitary services	784.0
Wholesale & retail trade	841.2
Finance & insurance	272.6
Real estate & rental	430.9
Hotels & personal services	164.8
Business services	1,244.9
Eating & drinking places	209.3
Automobile repair & service	97.4
Amusements	57.1
Health & educational & nonprofit	80.4
Federal government enterprises	106.2
State & local government enterprises	124.2
Total	$23,153.2

Source: Management Information Services, Inc.; 1989.

Table V.4

Impact of Proposed FY 1990 NASA Procurement Expenditures, Ranked by Industry

Industry Title	Percent of Total
Aircraft & parts	15.8
Ordnance & accessories	10.5
Radio, TV & communication equipment	6.0
Business services	5.4
Transportation & warehousing	4.2
Petroleum refining & related industries	4.1
Wholesale & retail trade	3.6
Electric, gas, & sanitary services	3.4
Crude petroleum & natural gas	3.4
Electronic components	3.1
Maintenance & repair construction	2.9
Primary nonferrous metals manufacturing	2.9
Primary iron & steel manufacturing	2.2
Other transportation equipment	2.1
Real estate & rental	1.9
Chemicals & selected chemical products	1.6
Motor vehicles & equipment	1.5
New construction	1.4
Rubber & miscellaneous plastics products	1.2
Finance & insurance	1.2
Communications, except radio & TV	1.1
Printing & publishing	1.1
Other fabricated metal products	1.0
Office, computing, & accounting machines	0.9
Eating & drinking places	0.9
Electrical transmission equipment	0.9
Heating, fabricated metal products	0.8
Miscellaneous machinery, except electrical	0.8
Hotels & personal services	0.7
Screw machine products & stampings	0.7
All Other 49 Industries	12.7
Total	100

Source: Management Information Services, Inc.; 1989.

Table V.5

Impact of Proposed 1990 NASA Procurement Expenditures,
Ranked by Relative Industry Size
(millions of dollars)

Rank		Output[a]
1	Ordnance and Accessories	$2,438
2	Aircraft and Parts	3,647
3	Radio, TV, and Communications Equipment	1,393
4	Electronic Components and Accessories	722
5	Primary Nonferrous Metals Manufactuirng	671
6	Engines and Turbines	152
7	Misc. Machinery, Except Electrical	184
8	Nonferrous Metal Ores Mining	41
9	Primary Iron and Steel Manufacturing	512
10	Iron and Ferroally Ores Mining	23
11	Wooden Containers	5
12	General Industrial Machinery	156
13	Electrical Transmission and Distribution Equipment	197
14	Optical, Ophthalmic, and Photographic Equipment and Supplies	137
15	Crude Petroleum and Natural Gas	776
16	Screw Machine Products and Stampings	156
17	Misc. Fabricated Metal Products	227
18	Metalworking Machinery and Equipment	98
19	Professional, Scientific, and Controlling Instruments and Supplies	142
20	Heating, Plumbing, and Fabricated Stuctural Metal Products	187

[a]Total output requirements generated by proposed FY 1990 NASA procurement expenditures

Source: Management Information Services, Inc., 1989

More important, virtually all of the industries in Table V.5 are basic manufacturing and/or high technology industries. While it has often been hypothesized that NASA spending supports the R & D, high technology, electronics, and related industries, the data in Table V.5 show that this is indeed true. However, it is not generally recognized that NASA spending plays a key role in supporting such basic U.S. industries as Iron and Steel Manufacturing, Nonferrous Metals Manufacturing, Ores Mining, and General Industrial Machinery.

This point is further emphasized in Table V.6, which shows (for selected industries) the indirect economic multipliers resulting from proposed FY 1990 NASA procurement expenditures. These multipliers represent, for the specific industry, the ratio of total to direct output requirements deriving from the 1990 NASA procurement budget. The higher the multiplier, the greater are the indirect requirements for the output of the industry generated by NASA procurement spending. Thus, the multiplier for the Electronic Components industry (6.7) is relatively high because large volumes of electronic equipment are required indirectly to produce NASA procurements. Conversely, the multiplier for the Aircraft and Parts Industry (1.2) is low because, although large procurements are made directly from this industry in the NASA program, the indirect requirements generated are relatively low. That is, not many airplanes are required indirectly to produce airplanes, but large amounts of electronic components are.

The data in Table V.6 show that, per dollar of direct procurement expenditure, NASA programs will result in widely varying indirect effects among industries. These range from indirect multipliers as high as 41.8 for Iron and Steel Manufacturing. 13.5 for Electric Lighting and Wiring Equipment, and 8.1 for Metalworking Machinery to lows near two for Motor Vehicles and Equipment and near one for Engines and Turbines and Aircraft and Parts. In other words, the 1990 NASA procurement budget is estimated to create, indirectly, nearly $7 dollars in sales in Electronic Components for every dollar directly procured in that industry, while it will create, indirectly, only about one dollar of sales indirectly in the Aircraft and Parts industry for every direct dollar of procurement in that industry.

As noted, this result is not surprising. Aircraft and motor vehicles are final products whose components do not enter into the production of other commodities, whereas electronic components are products required in the production of most other goods NASA purchases.

The support that NASA procurement provides (indirectly) for basic U.S. manufacturing industries noted in the discussion of Tables V.4 and V.5 is abundantly clear in Table V.6. Virtually all of the industries with the high multipliers are basic manufacturing industries (concentrated, as noted in the next chapter, in the "rustbelt" states).

This illustrates why it is necessary in assessing the impact of NASA procurement to examine the total impact on the economy, not just the direct procurement expenditures:

Table V.6

Indirect Economic Multipliers Resulting from Proposed NASA FY 1990 Procurement Expenditures -- Selected Industries

Industry	Multiplier[a]
Primary Iron and Steel Manufacturing	41.8
Primary Nonferrours Metals Manufacturing	30.0
Electric Lighting and Wiring Equipment	13.5
Rubber and Misc. Plastics Products	8.3
Metalworking Machinery	8.1
Electronic Components	6.7
Misc. Fabricated Metal Products	5.9
Electric, Gas, and Sanitary Services	4.5
Chemicals and Selected Chemical Products	3.2
Metal Containers	3.2
Wholesale and Retail Trade	3.0
Communications, except Radio and Television	2.4
Business Services	2.4
Electrical Transmission Equipment	2.3
Transportation and Warehousing	2.2
Electrical Transmission Equipment	2.3
Transportation and Warehousing	2.2
AVERAGE, ALL INDUSTRIES	2.1
Motor Vehicles and Equipment	2.0
Optical, Ophthalmic, and Photgraphic Equipment and Supplies	1.8
Petroleum Refining and Related Industries	1.8
Office, Computing, and Accounting Machines	1.7
Engines and Turbines	1.4
Aircraft and Parts	1.2
Miscellaneous Transportation Equipment	1.1

[a]Ratio of total to direct output requirements.

Source: Management Information Services, Inc., 1989.

- In terms of direct procurement, NASA requires about $12 million from the Iron and steel industry.
- In total, however, NASA procurement generates requirements for well over $500 million from this industry.

As discussed below, similar relationships exist between direct and indirect effects, and the consequent multipliers, at the state level.

Table V.7 shows the total employment created in each private sector industry by proposed 1990 NASA procurement expenditures.

The jobs estimated here are in private industry and do not include NASA employees or Federal government workers. If these categories of workers were included in the analysis the employment estimates would be increased by about 25,000 jobs. However, the focus here is on the jobs created in the private sector by NASA procurement spending. Further, it is self-evident that the NASA budget pays the salaries of NASA employees. Nevertheless, given the given the high concentration of scientists, engineers, and computer specialists employed directly by NASA, the Agency's employees must be taken into consideration when assessing the overall impact of NASA spending on the labor market for scientists, engineers, and skilled workers.

The data in Table V.7 illustrate that the distribution of jobs by industry differs in important respects from the distribution of sales shown in Table V.3. Thus, while large numbers of jobs are created in industries such as Aircraft, Ordnance, Business Services, and Communications Equipment, where the generated output requirements are large, employment of equal magnitude is also created in service industries such as Wholesale and Retail Trade, Transportation, Warehousing, Restaurants, and Hotels.

Employment created in these latter industries is large because they are very labor intensive and have low capital labor ratios and low productivity. Because of these factors the types of jobs created in these industries is relatively low skilled and pays relatively low wages.

Nevertheless, it is important to note that NASA procurement spending generates large numbers of jobs in industries not usually associated with the Space Program or the aerospace sector. In fact, as Table V.7 shows, 1990 NASA procurement spending is estimated to create more jobs in Wholesale and Retail Trade than in the Communications Equipment industry, and to generate more employment in Transportation and Warehousing than in the Electronic Components industry.

Table V.8 shows the employment created by NASA procurement disaggregated among major occupational groups, and Table V.9 further disaggregates this employment among 115 occupations selected from the 475 occupations for which job requirements were estimated.[1] These tables show that, as expected, the jobs created are disproportionately in technical, skilled, and specialized occupations. Thus, 1990 NASA procurement spending will create jobs for 17,000 Engineers (seven

Table V.7

Employment Created in Each Industry by Proposed FY 1990
NASA Procurement Expenditures

Industry Title	Employment
Livestock & livestock products	322
Other agricultural products	2,568
Forestry & fishery products	111
Agricultural, forestry & fishery services	829
Iron & ferroalloy ores mining	144
Nonferrous metal ores mining	419
Coal mining	511
Crude petroleum & natural gas	3,051
Stone & clay mining & quarrying	216
Chemical & fertilizer mineral mining	57
New construction	3,750
Maintenance & repair construction	7,132
Ordnance & accessories	20,651
Food & kindred products	556
Tobacco manufactures	0
Broad & narrow fabrics, yarn & thread mills	915
Miscellaneous textile goods & floor coverings	179
Apparel	1,190
Miscellaneous fabricated textile products	348
Lumber & wood products, exc. containers	1,475
Wood containers	65
Household furniture	260
Other furniture & fixtures	143
Paper & allied products	837
Paperboard containers & boxes	440
Printing & publishing	3,028
Chemicals & selected chemical products	1,832
Plastics & synthetic materials	552
Drugs, cleaning & toilet preparations	287
Paints & allied products	193
Petroleum refining & related industries	1,225
Rubber & miscellaneous plastics products	3,058
Leather tanning & finishing	18
Footwear & other leather products	110
Glass & glass products	370
Stone & clay products	1,274
Primary iron & steel manufacturing	3,400
Primary nonferrous metals manufacturing	4,035
Metal containers	87
Heating, fabricated metal products	2,278
Screw machine products & stampings	1,436
Other fabricated metal products	2,801

Table V.7 (continued)

Employment Created in Each Industry by Proposed FY 1990
NASA Procurement Expenditures

Industry Title	Employment
Engines & turbines	925
Farm & garden machinery	87
Construction & mining machinery	291
Materials handling machinery	290
Metalworking machinery	1,481
Special industry machinery	210
General industrial machinery	1,547
Miscellaneous machinery, except electrical	2,568
Office, computing, & accounting machines	1,998
Service industry machines	297
Electrical transmission equipment	2,317
Household appliances	175
Electric lighting & wiring equipment	723
Radio, TV & communication equipment	10,319
Electronic components	10,918
Miscellaneous electrical machinery	442
Motor vehicles & equipment	1,664
Aircraft & parts	33,808
Other transportation equipment	5,785
Professional & scientific supplies	1,921
Optical & photographic equipment	996
Miscellaneous manufacturing	510
Transportation & warehousing	12,910
Communications, except radio & TV	2,249
Radio & TV broadcasting	518
Electric, gas, & sanitary services	3,136
Wholesale & retail trade	19,374
Finance & insurance	3,677
Real estate & rental	1,806
Hotels & personal services	4,761
Business services	21,748
Eating & drinking places	6,812
Automobile repair & service	1,044
Amusements	1,219
Health & educational & nonprofit	2,800
Federal government enterprises	2,415
State & local government enterprises	1,667
Total	236,679

Source: Management Information Services, Inc.; 1989.

Table V.8

Jobs Created by Proposed FY 1990 NASA Procurement Expenditures -- Major Occupational Group

Major Occupational Category	Jobs
Managerial and Professional Specialty Occupations	
Executive, administrative, and managerial occupations	26,431
Professional specialty occupations	33,073
Technical, Sales, and Administrative Support Occupations	
Technicians and related support occupations	11,292
Sales occupations	16,319
Administrative support occupations, including clerical	35,399
Service Occupations	
Protective service occupations	1,796
Service occupations, except protective	12,915
Farming, Forestry, and Fishing Occupations	
Farm operators and managers	1,401
Other agricultural and related occupations	1,878
Forestry and logging occupations	309
Fishers, hunters, and trappers	71
Precision Production, Craft, and Repair Occupations	
Mechanics and repairers	12,763
Construction trades	9,551
Extractive occupations	1,129
Precision production occupations	20,930
Operators, Fabricators, and Laborers	
Machine operators, assemblers, and inspectors	32,010
Transportation and material moving occupations	11,083
Handlers, equipment cleaners, helpers, and laborers	8,330
Total	236,679

Source: Management Information Services, Inc.; 1989.

Table V.9

Jobs Created by Proposed 1990 NASA Procurement Expenditures Within Selected Occupations

Occupation	Jobs
Financial Managers	683
Accountants and Auditors	2,604
Management Analysts	355
Personnel and Training Specialists	686
Buyers, Wholesale and Retail Trade	250
Inspectors, Except Construction	139
Architects	181
Metallurgical Engineers	344
Aerospace Engineers	3,441
Chemical Engineers	476
Electrical and Electronics Engineers	5,304
Industrial Engineers	2,288
Mechanical Engineers	2,413
Surveyors	46
Computer Systems Analysts	1,620
Statisticians	40
Chemists	412
Geologists and Geodeists	256
Biological and Life Scientists	27
Registered Nurses	367
Pharmacists	139
Economists	316
Psychologists	103
Lawyers	1,099
Technical Writers	329
Designers	1,029
Photographers	203
Public Relations Specialists	319
Clinical Laboratory Technicians	40
Electrical and Electronics Engineering Technicians	2,404
Drafting Occupations	1,174
Computer Programmers	2,736
Tool Programmers	8
Sales Engineers	167
Sales Representatives	3,000
Cashiers	2,442
Supervisors, Financial Records	173
Computer Operators	2,555
Secretaries	7,733
Receptionists	650

Source: Management Information Services, Inc., 1989.

Table V.9 (Continued)

Occupation	Jobs
Personnel Clerks	146
Bookkeepers and Accounting Clerks	3,424
Payroll Clerks	683
Telephone Operators	226
Dispatchers	327
Production Coordinators	1,307
Shipping and Receiving Clerks	1,284
Weighers and Checkers	299
General Office Clerks	1,333
Proofreaders	36
Supervisors, Guards	146
Kitchen Workers	184
Janitors and Cleaners	3,458
Transportation Attendants	224
Horticultural Specialty Farmers	9
Farm Workers	1,142
Graders and Sorters	32
Timber Cutting and Logging Occupations	275
Automobile Mechanics	945
Bus and Truck Engine Mechanics	694
Small Engine Repairers	156
Heavy Equipment Mechanics	790
Machinery Maintenance Occupations	76
Data Processing Equipment Repairers	361
Telephone Installers	840
Miscellaneous Electronic Equipment Repairers	238
Heating and Air Conditioning Mechanics	416
Mechanical Control Repairers	91
Millwrights	224
Brickmasons and Stonemasons	272
Carpenters	2,490
Electricians	1,713
Glaziers	85
Structural Metal Workers	163
Supervisors, Extractive Occupations	311
Explosives Workers	139
Mining Machine Operators	110
Miscellaneous Mining Occupations	190
Tool and Die Makers	1,272
Machinists	3,476

Source: Management Information Services, Inc., 1989.

Table V.9 (Continued)

Occupation	Jobs
Precision Grinders	154
Sheetmetal Workers	1,523
Upholsterers	126
Patternmakers	182
Electrical Equipment Assemblers	2,047
Inspectors and Testers	1,556
Water and Sewage Treatment Plant Operators	145
Drilling Machine Operators	467
Forging Machine Operators	68
Metal Plating Machine Operators	394
Sawing Machine Operators	188
Photoengravers and Lithographers	88
Textile Sewing Machine Operators	1,024
Packaging and Filling Machine Operators	908
Separating Machine Operators	139
Crushing and Grinding Machine Operators	63
Photographic Process Machine Operators	156
Welders and Cutters	2,375
Assemblers	6,523
Production Inspectors and Examiners	3,579
Truck Drivers	5,892
Parking Lot Attendants	57
Locomotive Operating Occupations	202
Sailors and Deckhands	44
Operating Engineers	320
Hoist and Winch Operators	113
Crane and Tower Operators	490
Excavating and Loading Machine Operators	142
Grader, Dozer, and Scraper Operators	177
Miscellaneous Material Moving Equipment Operators	414
Helpers, Construction Trades	256
Helpers, Extractive Occupations	19
Construction Laborers	956
Stevedores	102
Stock Handlers and Baggers	884
Total, All Occupations*	236,679

*Totals include data for the 360 occupations not listed separately.

Source: Management Information Services, Inc., 1989.

percent of total employment created), including 3,441 Aeronautical engineers (6.3 percent of the total employed in private industry), 5,300 Electrical Engineers (1.3 percent of the total employed in private industry), 2,600 Accountants, 400 Chemists, 1,100 Lawyers, 1,000 Designers, 4,600 Engineering Technicians, 1,600 Computer Systems Analysts, 2,000 Industrial Machinery Repairers, 2,500 Carpenters, 1,500 Sheetmetal Workers, 3,500 Machinists, and 2,400 Welders.

However, Tables V.8 and V.9 also demonstrate that the Space Program generates many jobs for virtually all categories of workers. In fact, the 1990 NASA procurement budget will create more jobs (3,400) for Bookkeepers than for Aeronautical Engineers, it will create more jobs (7,700) for Secretaries than for Electrical Engineers, more jobs (700) for Personnel and Labor Relations Workers than for Chemists, more jobs (3,000) for Cashiers than for Accountants, more jobs for Shipping Clerks (1,300) than for Designers, more jobs (2,200) for Stock Clerks than for Computer Systems Analysts, more jobs (5,900) for Truck Drivers than for Machinists, and more jobs for Janitors (3,500) than for Welders.

This again illustrates the pervasive nature of the economic and employment impacts of the Space Program.

Nevertheless, while the total number of jobs created in different occupations is important, these absolute numbers do not convey the significance of the NASA programs for specific occupations, especially the science, engineering, and related occupations, and several considerations are in order:

- First, there are many times more janitors, clerks, salespersons, etc., than aerospace engineers, computer scientists, or physicists, and a comparison of absolute numbers can be misleading.
- Second, the time and the money required to educate a scientist, engineer, or skilled worker represents a large private and public investment in human capital.
- Third, there is widespread concern that the U.S. faces potential shortages within many science and engineering occupations during the 1990s.

A more meaningful comparison of the effect of NASA spending is given in Table V.10, which shows the estimated impact of FY 1990 NASA procurement on the demand for specific occupations, ranked by the percent impact on total jobs within the specific occupation.

This table shows how important NASA procurement spending is in influencing the private sector labor market for Engineers, Scientists, Computer Specialists, Technicians, and skilled workers in many occupations. In fact, with possibly one or two exceptions, all of the occupations impacted the most heavily are within the above mentioned categories. Broadly speaking, the influence of NASA spending on the jobs in these occupations will be 20 or 30 times higher than its

Table V.10

Jobs Created by Proposed FY 1990 NASA Procurement Expenditures Within Selected Occupations, Ranked by Relative Job Impact

Rank[a]		Jobs Created
1	Aerospace Engineers	3,441
2	Mechanical Engineering Technicians	577
3	Electronic Repairers, Communications Equipment	915
4	Inspectors and Testors	1,556
5	Aircraft Engine Mechanics	881
6	Electrical Engineers	5,304
7	Mathematicians	123
8	Electrical Equipment Asseblers	2,047
9	Solderers and Brazers	395
10	Metallurgical Engineers	344
11	Industrial Engineers	2,288
12	Operations and Systems Researchers	1,359
13	Electrical Technicians	2,404
14	Mechanical Engineers	2,413
15	Grinding and Polishing Machine Operators	1,266
16	Metal Plating Machine Operators	394
17	Tool and Die Makers	1,272
18	Misc. Engineering Technicians	1,653
19	Computer Programmers	2,736
20	Marine Engineers	98
21	Purchasing Agents and Buyers	1,472
22	Technical Writers	329
23	Chemical Engineers	476
24	Computer Systems Analysts	1,620
25	Misc. Engineers	986
26	Misc. Science Technicians	344
27	Drafting Occupations	1,174
28	Civil Engineers	897
29	Mining Engineers	52
30	Chemists, except Biochemists	412

[a]Ranked on the basis of the percent job impact on the occupation.

Source: Management Information Services, Inc., 1989

overall impact on the economy. While it has frequently been stated how important the Space Program is in creating demand for these occupations, Table V.10 clearly illustrates this.

This table also contains some unexpected findings. While it is not surprising to see that NASA programs create demand in private industry for Aerospace Engineers, Aircraft Engine Mechanics, and Computer Programmers, it is important to note that NASA spending is also important in the job market for Inspectors and Testors, Assemblers, Solderes, Machine Operators, and Tool and Diemakers.

A point again worth noting is that these data exclude all NASA employees. Since these employees are overwhelmingly concentrated in the Science and Engineering specialties, if they were included the impact on Scientists and Engineers would be even more pronounced. Thus the data in Table V.10 actually give a somewhat conservative estimate of the the impact of NASA programs on the employment requirements for many types of scientists and engineers. However, this is not true for the manufacturing-related occupations in this table, since these are concentrated in private industry.

Footnotes

1. The jobs created for 475 all-inclusive occupations are given in the appendix.

VI. THE BENEFITS TO EACH STATE

One of the more important questions about the economic effects of the Space Program that must be resolved is how these benefits are distributed among the states. Obviously, the states of Florida, Alabama, and Texas contain major NASA facilities and benefit substantially from Agency programs, as does California, due to the concentration of the aerospace industry in the southern part of the state. But how are the indirect economic benefits of the NASA programs distributed among the states? Does the U.S. Space program have significant effects on most states or are the benefits concentrated in only a relatively few? These types of questions have not heretofore been adequately answered, and they are the focus of this chapter.

The estimated FY 1990 NASA procurement awards classified by type of contractor and by state are given in Table VI.1, the percent distribution of these is shown in Table VI.2, and the ranks among the states of the prime contract awards are illustrated in Figure VI.1. The data in these exhibits appear to indicate that the economic benefits of the Space Program are heavily concentrated in four or five states and that the other 45 or so gain little from NASA procurement spending. Figure VI.1 indicates that five states -- California, Texas, Florida, Maryland, and Alabama -- receive 68 percent of the NASA procurement spending, and that the remainder is distributed in relatively insignificant amounts to all the other states. This is the conventional wisdom: the economic benefits of expenditures for the U.S. Space Program flow primarily to only a few regions of the nation and most states gain little from this spending.

However, this impression is wrong. As we demonstrate below, the economic benefits of the Space Program are widely distributed throughout the nation, and among of the biggest state "winners" are many that few analysts perceive as being closely tied to the Program.

Table VI.3 shows the total (direct plus indirect) economic and employment benefits of the proposed FY 1990 NASA procurement budget to every state. This table demonstrates that in terms of industry sales and jobs every state benefits substantially from the U.S. Space Program. These data are important, for they refute the widespread notion that the NASA budget benefits four or five states at the expense of the rest of the nation.

However, even these data are aggregate and in one sense obscure relevant information, and to further assess the state-specific benefits and their distributions we have developed several rankings of the states.

Table VI.4 ranks the top 20 states on the basis of the total sales generated by the Space Program. Table VI.5 ranks the top 20 states on the basis of the per capita employment created by the Space Program. Table VI.6 ranks the top 20 states on the basis of the economic benefits created indirectly within each state by the Space Program.

Table VI.1

Estimated FY 1990 NASA Procurement Awards by Type of Contractor and by State

State	Total	Business Prime	Business Subcontract	Education Nonprofit	Federal Government
		(millions of dollars)			
Alabama	627.6	487.2	99.6	18.3	22.5
Alaska	11.3	0.1	0.1	3.4	7.7
Arizona	112.9	9.2	76.5	16.3	11.0
Arkansas	5.0	0.1	0.4	0.2	4.3
California	3,728.9	2,251.3	744.5	541.0	192.2
Colorado	217.5	75.0	105.7	18.0	18.8
Connecticut	144.1	84.1	51.1	3.3	5.6
Delaware	12.5	3.4	6.3	1.0	1.9
Dist. Columbia	99.4	40.1	1.8	27.9	29.6
Florida	1,176.4	858.5	249.5	7.0	61.3
Georgia	55.2	13.6	11.4	5.6	24.7
Hawaii	29.6	0.5	1.3	7.9	19.9
Idaho	3.2	0.0	0.0	0.7	2.5
Illinois	61.1	7.2	25.9	11.4	16.5
Indiana	28.6	8.2	10.1	4.6	5.7
Iowa	12.1	0.1	1.5	9.3	1.1
Kansas	45.4	23.5	10.6	1.8	9.5
Kentucky	13.6	0.0	0.8	0.7	12.1
Louisiana	347.4	312.3	22.9	2.1	10.1
Maine	4.4	0.0	0.1	0.6	3.6
Maryland	821.3	700.1	37.6	53.8	29.8
Massachusetts	141.8	24.5	54.5	53.0	9.8
Michigan	37.3	8.2	10.5	13.2	5.5
Minnesota	32.8	8.7	19.8	2.3	2.0
Mississippi	108.3	91.3	5.8	2.7	8.5
Missouri	41.4	13.1	17.2	3.3	7.8
Montana	2.1	0.0	0.1	0.4	1.6
Nebraska	7.4	0.0	1.1	0.6	5.8
Nevada	7.5	0.6	3.1	0.1	3.7
New Hampshire	19.7	2.4	9.0	6.6	1.7

Table VI.1 (continued)

Estimated FY 1990 NASA Procurement Awards by Type of Contractor and by State

State	Total	Business Prime	Business Subcontract	Education Nonprofit	Federal Government
		(millions of dollars)			
New Jersey	256.7	132.3	111.4	4.2	8.8
New Mexico	83.4	42.8	17.9	9.0	13.7
New York	154.3	44.0	74.0	22.6	13.7
North Carolina	40.6	0.7	2.7	6.8	30.4
North Dakota	4.0	0.1	0.0	0.1	3.8
Ohio	245.4	163.3	24.7	23.7	33.7
Oklahoma	16.5	0.0	1.1	4.1	11.3
Oregon	9.7	2.0	4.4	1.6	1.7
Pennsylvania	152.2	107.7	22.8	11.8	9.9
Rhode Island	8.4	0.7	2.4	2.4	2.9
South Carolina	22.7	0.2	0.2	0.8	21.3
South Dakota	5.3	0.1	2.3	0.5	2.5
Tennessee	40.7	20.0	6.3	6.2	8.1
Texas	1,173.9	851.5	184.3	59.6	78.5
Utah	561.1	551.6	4.2	2.1	3.2
Vermont	2.6	0.5	1.7	0.1	0.4
Virginia	486.9	325.2	65.7	26.2	69.8
Washington	40.0	12.1	2.9	6.1	19.0
West Virginia	1.2	0.1	0.1	0.2	0.7
Wisconsin	36.8	19.3	2.3	12.0	3.2
Wyoming	1.8	0.0	0.1	0.2	1.4
Total	11,300.0	7,297.6	2,110.2	1,017.4	874.8

Source: Historical NASA Procurement and Budget documents; and MISI; 1989.

Table VI.2

Estimated FY 1990 NASA Procurement Awards by Type of Contractor and by State (Percent Distribution)

State	Total	Business Prime	Business Subcontract	Education Nonprofit	Federal Government
	(percent of US total)				
Alabama	5.6	6.7	4.7	1.8	2.6
Alaska	0.1	0.0	0.0	0.3	0.9
Arizona	1.0	0.1	3.6	1.6	1.3
Arkansas	0.0	0.0	0.0	0.0	0.5
California	33.0	30.8	35.3	53.2	22.0
Colorado	1.9	1.0	5.0	1.8	2.1
Connecticut	1.3	1.2	2.4	0.3	0.6
Delaware	0.1	0.0	0.3	0.1	0.2
Dist. Columbia	0.9	0.5	0.1	2.7	3.4
Florida	10.4	11.8	11.8	0.7	7.0
Georgia	0.5	0.2	0.5	0.5	2.8
Hawaii	0.3	0.0	0.1	0.8	2.3
Idaho	0.0	0.0	0.0	0.1	0.3
Illinois	0.5	0.1	1.2	1.1	1.9
Indiana	0.3	0.1	0.5	0.5	0.7
Iowa	0.1	0.0	0.1	0.9	0.1
Kansas	0.4	0.3	0.5	0.2	1.1
Kentucky	0.1	0.0	0.0	0.1	1.4
Louisiana	3.1	4.3	1.1	0.2	1.2
Maine	0.0	0.0	0.0	0.1	0.4
Maryland	7.3	9.6	1.8	5.3	3.4
Massachusetts	1.3	0.3	2.6	5.2	1.1
Michigan	0.3	0.1	0.5	1.3	0.6
Minnesota	0.3	0.1	0.9	0.2	0.2
Mississippi	1.0	1.3	0.3	0.3	1.0
Missouri	0.4	0.2	0.8	0.3	0.9
Montana	0.0	0.0	0.0	0.0	0.2
Nebraska	0.1	0.0	0.1	0.1	0.7
Nevada	0.1	0.0	0.1	0.0	0.4
New Hampshire	0.2	0.0	0.4	0.6	0.2

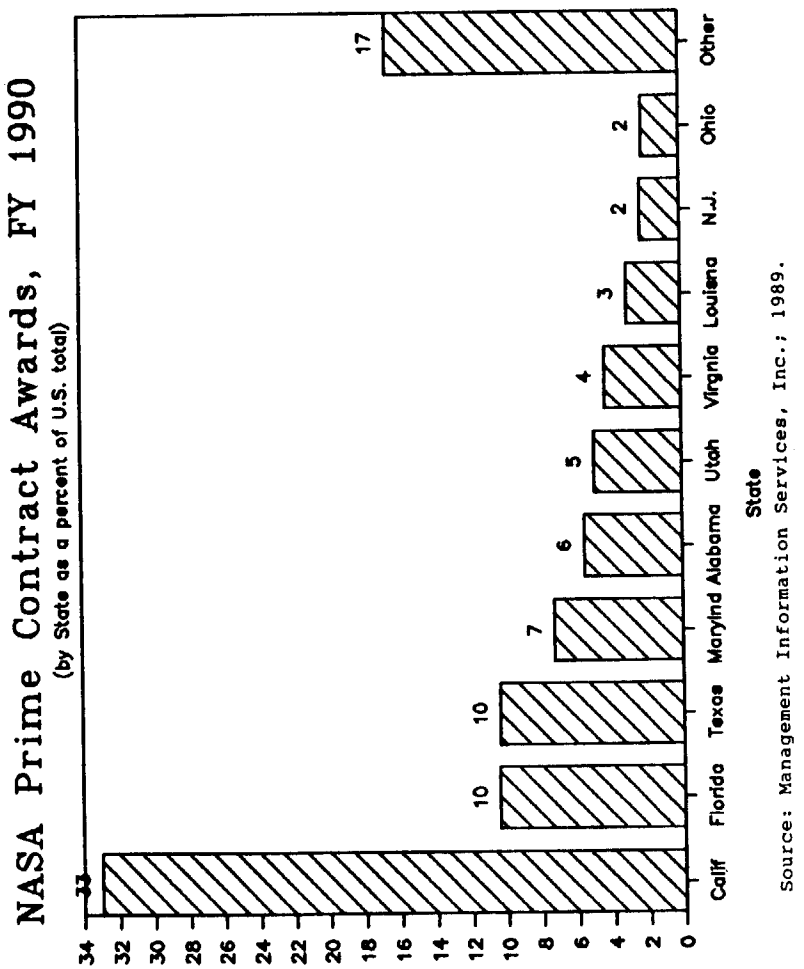
Table VI.2 (continued)

Estimated FY 1990 NASA Procurement Awards by Type of Contractor and by State (Percent Distribution)

State	Total	Business Prime	Business Subcontract	Education Nonprofit	Federal Government
	(percent of US total)				
New Jersey	2.3	1.8	5.3	0.4	1.0
New Mexico	0.7	0.6	0.8	0.9	1.6
New York	1.4	0.6	3.5	2.2	1.6
North Carolina	0.4	0.0	0.1	0.7	3.5
North Dakota	0.0	0.0	0.0	0.0	0.4
Ohio	2.2	2.2	1.2	2.3	3.9
Oklahoma	0.1	0.0	0.1	0.4	1.3
Oregon	0.1	0.0	0.2	0.2	0.2
Pennsylvania	1.3	1.5	1.1	1.2	1.1
Rhode Island	0.1	0.0	0.1	0.2	0.3
South Carolina	0.2	0.0	0.0	0.1	2.4
South Dakota	0.0	0.0	0.1	0.0	0.3
Tennessee	0.4	0.3	0.3	0.6	0.9
Texas	10.4	11.7	8.7	5.9	9.0
Utah	5.0	7.6	0.2	0.2	0.4
Vermont	0.0	0.0	0.1	0.0	0.0
Virginia	4.3	4.5	3.1	2.6	8.0
Washington	0.4	0.2	0.1	0.6	2.2
West Virginia	0.0	0.0	0.0	0.0	0.1
Wisconsin	0.3	0.3	0.1	1.2	0.4
Wyoming	0.0	0.0	0.0	0.0	0.2
Total	100	100	100	100	100

Source: Management Information Services, Inc.; 1989.

Figure VI.1



Source: Management Information Services, Inc.; 1989.

Table VI.3

Estimated Sales and Jobs Created in Each State by Proposed FY 1990 NASA Procurement Expenditures

State	Sales (millions)	(% of US)	Employment (number)	(% of US)
Alabama	$858.2	3.7	8,582	3.6
Alaska	35.5	0.2	236	0.1
Arizona	229.6	1.0	2,424	1.0
Arkansas	89.0	0.4	876	0.4
California	6,766.6	29.2	70,332	29.7
Colorado	490.3	2.1	5,381	2.3
Connecticut	601.1	2.6	6,224	2.6
Delaware	32.7	0.1	291	0.1
Dist. Columbia	75.2	0.3	990	0.4
Florida	1,297.5	5.6	14,756	6.2
Georgia	299.7	1.3	3,224	1.4
Hawaii	23.0	0.1	278	0.1
Idaho	21.4	0.1	242	0.1
Illinois	549.2	2.4	5,657	2.4
Indiana	348.3	1.5	3,253	1.4
Iowa	94.7	0.4	1,050	0.4
Kansas	172.0	0.7	1,697	0.7
Kentucky	142.4	0.6	1,358	0.6
Louisiana	535.0	2.3	4,583	1.9
Maine	36.0	0.2	386	0.2
Maryland	994.3	4.3	11,122	4.7
Massachusetts	382.3	1.7	4,208	1.8
Michigan	518.9	2.2	4,582	1.9
Minnesota	164.3	0.7	1,791	0.8
Mississippi	231.9	1.0	2,146	0.9
Missouri	342.3	1.5	3,427	1.4
Montana	18.7	0.1	180	0.1
Nebraska	47.7	0.2	566	0.2
Nevada	30.2	0.1	379	0.2
New Hampshire	58.7	0.3	626	0.3

Table VI.3 (continued)

Estimated Sales and Jobs Created in Each State by Proposed FY 1990 NASA Procurement Expenditures

State	Sales (millions)	(% of US)	Employment (number)	(% of US)
New Jersey	506.0	2.2	5,411	2.3
New Mexico	135.5	0.6	1,242	0.5
New York	711.1	3.1	7,820	3.3
North Carolina	231.3	1.0	2,450	1.0
North Dakota	18.0	0.1	183	0.1
Ohio	928.7	4.0	8,545	3.6
Oklahoma	158.7	0.7	1,358	0.6
Oregon	67.3	0.3	731	0.3
Pennsylvania	602.2	2.6	5,955	2.5
Rhode Island	32.3	0.1	347	0.1
South Carolina	109.5	0.5	1,139	0.5
South Dakota	18.3	0.1	221	0.1
Tennessee	209.1	0.9	2,237	0.9
Texas	2,105.4	9.1	19,528	8.3
Utah	590.8	2.6	5,895	2.5
Vermont	21.1	0.1	226	0.1
Virginia	631.2	2.7	6,666	2.8
Washington	308.4	1.3	3,173	1.3
West Virginia	61.0	0.3	502	0.2
Wisconsin	193.0	0.8	1,991	0.8
Wyoming	20.0	0.1	210	0.1
Total	$23,153.2	-	236,679	-

Source: Management Information Services, Inc.; 1989.

Table VI.4

Ranking of the Top 20 States on the Basis of Total Industry Sales Generated by Proposed FY 1990 NASA Procurement Expenditures

Rank	
1.	California
2.	Texas
3.	Florida
4.	Maryland
5.	Ohio
6.	Alabama
7.	New York
8.	Virginia
9.	Pennsylvania
10.	Connecticut
11.	Utah
12.	Illinois
13.	Louisiana
14.	Michigan
15.	New Jersey
16.	Colorado
17.	Massachusetts
18.	Indiana
19.	Missouri
20.	Washington

Source: Management Information Services, Inc., 1989

Table VI.5

Ranking of the Top 20 States on the Basis of Jobs Created Per Capita by Proposed FY 1990 NASA Procurement Expenditures

Rank	
1.	Utah
2.	California
3.	Maryland
4.	Alabama
5.	Connecticut
6.	Colorado
7.	Florida
8.	Texas
9.	Virginia
10.	Louisiana
11.	Ohio
12.	Mississippi
13.	New Mexico
14.	New Jersey
15.	Washington
16.	Kansas
17.	Missouri
18.	Arizona
19.	Indiana
20.	New Hampshire

Source: Management Information Services, Inc., 1989

Table VI.6

Ranking of the Top 20 States on the Basis of Industry Sales Generated Indirectly in the State by Proposed FY 1990 NASA Procurement Expenditures

Rank	
1.	California
2.	Texas
3.	Ohio
4.	New York
5.	Illinois
6.	Michigan
7.	Connecticut
8.	Pennsylvania
9.	Indiana
10.	Missouri
11.	Colorado
12.	Washington
13.	New Jersey
14.	Georgia
15.	Massachusetts
16.	Alabama
17.	North Carolina
18.	Louisiana
19.	Maryland
20.	Tennessee

Source: Management Information Services, Inc., 1989

Focussing first on VI.4, it is observed that in terms of total sales generated the prime contract award states of California, Texas, Florida, Maryland, and Alabama still clearly dominate. This is to be expected, since the total economic benefits are the sum of the direct benefits and the indirect benefits. What is interesting in this table, however, is that we are beginning to see states emerging as "winners" that get little direct NASA procurement funding. These states include New York, Pennsylvania, Illinois, Michigan, New Jersey, Colorado, and Indiana.

Table VI.5 ranks the states on the basis of the employment created (directly and indirectly) by proposed FY 1990 NASA procurement, normalized by each state's forecast 1990 population. This is an important evaluation criterion, for it indicates how relatively important the jobs created (listed in Table VI.3) are in relation to the number of workers in the state. Obviously, a given number of jobs created in a small state such as Wyoming or New Hampshire are much more significant to the state than the same number of jobs created in a large state such as California, Texas, or New York. Again we observe states beginning to emerge as clear winners that few would normally associate closely with the Space Program. These include Colorado, Indiana, Arizona, New Jersey, Connecticut, Washington, Kansas, Missouri, and New Hampshire.

Tables VI.3 through VI.5 are based on the total impacts of NASA spending and, as noted, are dominated by the five states receiving the large prime contract awards. Table VI.6 ranks the top 20 states on the basis of the indirect benefits received from proposed FY 1990 NASA procurement -- the economic activity generated within a state by the indirect effects of NASA procurement in all the other states. This table can shows there are substantial benefits to those states that do not receive large prime contract awards from NASA.

Once again, California and Texas dominate the ranking of winners in this table, but abstracting from this, the results are rather interesting. First of all, several of the major prime contract award states, such as Florida and Utah -- the latter of which receives the highest per capita benefits -- no long even appear among the top 20 ranked states. Thus, while these two states benefit substantially from the direct procurement awards, they receive relatively little indirect economic stimulus from NASA-induced business in other states.

Second, other major prime contract award states, such as Alabama, Louisiana, and Virginia, are now ranked much lower. Again, these states do not contain the types of industries that benefit from the indirect economic stimulus of the NASA expenditures.

Third, Ohio, which ranks tenth in terms of prime contract awards, now ranks third on the basis of its industrial infrastructure.

Finally, and most interesting, we find a new set of states identified as major (indirect) beneficiaries of the U.S. Space Program. These include the major manufacturing states of New York, Illinois, Michigan, Pennsylvania, Indiana, Missouri, New Jersey, and

Wisconsin. These states represent the manufacturing heartland of the U.S. and benefit substantially by producing the products required by the prime contractors and the subcontractors to NASA. Other states noteworthy in Table VI.6 include Georgia, Massachusetts, North Carolina, and Tennessee.

To illustrate the importance of the indirect impact of NASA procurement on different states we derived the economic multipliers illustrated in Table VI.7. These are computed by deriving the total (direct plus indirect) sales generated in the state by proposed FY 1990 NASA procurement by the direct procurement expenditures in the state. The higher the multiplier, the greater the importance of NASA procurement in generating indirect economic benefits in the state. More significant perhaps, the higher the multiplier, the greater the importance of the "hidden" indirect benefits of NASA spending to the state. Thus:

- For every dollar Michigan will likely receive directly in proposed FY 1990 NASA procurement funds, it will receive $14 indirectly in procurement-induced business.
- For every dollar Illinois will likely receive directly in proposed FY 1990 NASA procurement funds, it will receive $10 indirectly in procurement-induced business.
- For every dollar North Carolina will likely receive directly in proposed FY 1990 NASA procurement funds, it will receive $6 indirectly in procurement-induced business.
- For every dollar New York will likely receive directly in proposed FY 1990 NASA procurement funds, it will receive $5 indirectly in procurement-induced business.

None of the above four states -- Michigan, Illinois, North Carolina, New York -- are traditionally considered to be closely linked to NASA spending, yet each stands to gain considerably from the proposed FY 1990 NASA procurement expenditures.

Figure VI.2 illustrates the pervasiveness of the indirect benefits to the states of NASA procurement spending. States are grouped according to the size of their indirect multipliers:

- Six states have multipliers greater than 10 -- Arkansas (5), Indiana (12), Kentucky (10), Michigan (14), Oklahoma (9), and Washington (77)
- Five states have multipliers between 7 and 9 -- Illinois (9), Iowa (8), Missouri (8), Nebraska (7), and Oregon (7)
- Twelve states have multipliers between 4 and 6 -- Connecticut (4), Georgia (6), Kansas (4), Minnesota (5), Nevada (4), New York (5), North Carolina (6), Ohio (4), Pennsylvania (4), Rhode Island (4), South Carolina (5), Tennessee (5), and Wisconsin (5)

Table VI.7

Economic Multipliers for Selected States Resulting From Proposed FY 1990 NASA Procurement Expenditures

	Multiplier[a]
Michigan	14.0 to 1
Indiana	12.0 to 1
Illinois	9.8 to 1
Missouri	8.3 to 1
Oregon	6.7 to 1
North Carolina	5.6 to 1
Georgia	5.5 to 1
Wisconsin	5.2 to 1
Tennessee	5.1 to 1
New York	4.6 to 1
Pennsylvania	4.0 to 1
Kansas	3.8 to 1
Ohio	3.8 to 1
Massachusetts	2.7 to 1
Mississippi	2.1 to 1
Arizona	2.0 to 1
New Jersey	2.0 to 1
Texas	1.8 to 1
California	1.8 to 1
Alabama	1.4 to 1
Florida	1.1 to 1

[a]Ratio of total (direct plus indirect) economic benefits to direct economic benefits.

Source: Management Information Services, Inc., 1989.

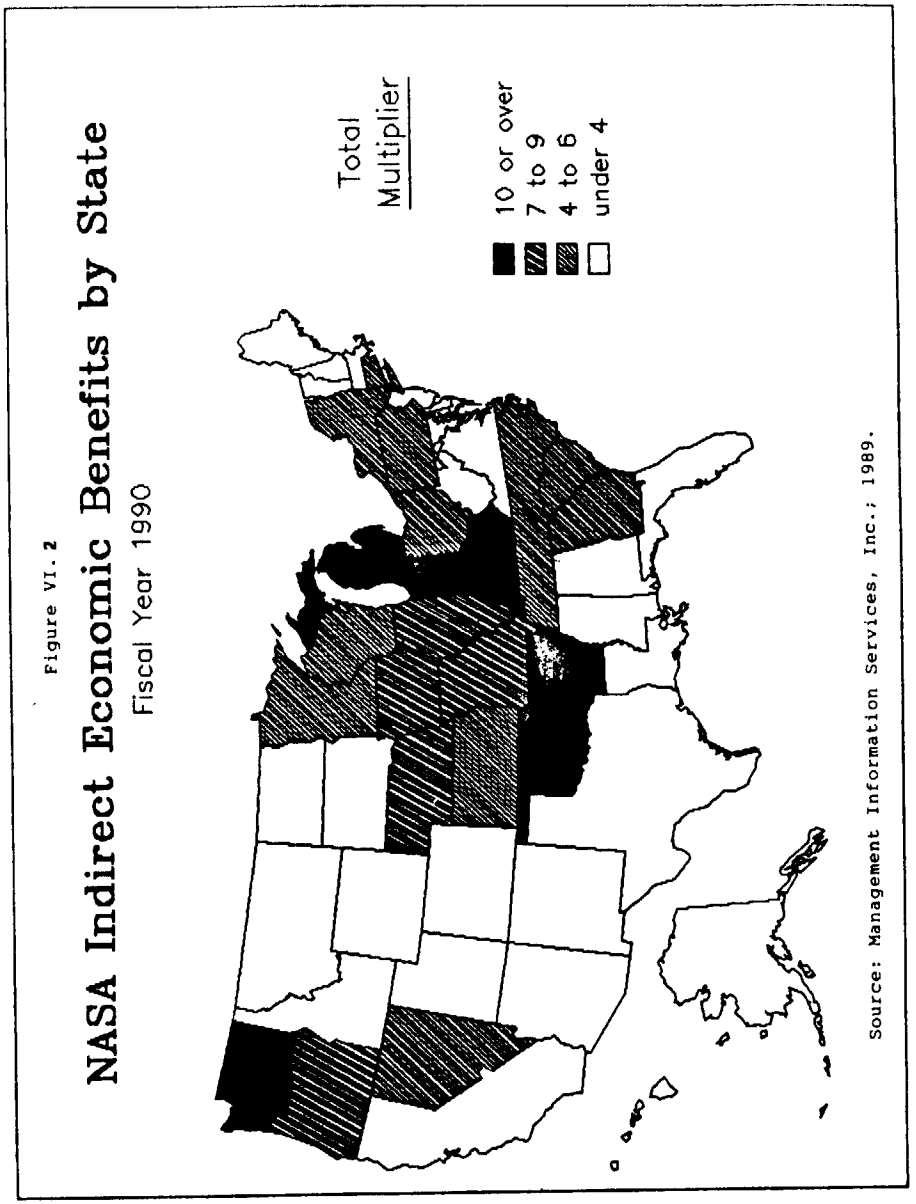


Figure VI.2

o All of the other states have multipliers less than 4

These findings are significant. Observing only the direct NASA procurement spending in a state can give a misleading picture of the importance of NASA procurement to the economic well being of that state, and the indirect economic benefits identified here must also be considered. To give only one example, focusing exclusively on the direct procurement expenditures in Indiana would indicate that the state will receive only $29 million out of the entire proposed FY 1990 NASA procurement budget. However, in reality, when the indirect effects of the procurement spending are taken into account Indiana emerges as a major "winner" from the program, and is likely to benefit from $350 million in increased 1990 gross state product due to NASA procurement.

The above analysis allows us to categorize the states which are directly or indirectly (or both) the major benefactors of the U.S. Space Program. These are shown in Table VI.8. Category A contains those states which will receive the major FY 1990 NASA prime contract awards and which have been traditionally assumed to be tied closely to the Space Program. Category B identifies those states that will likely benefit significantly on a per capita basis and/or indirectly from NASA procurement and which have not traditionally been tied closely to the Space Program or to the NASA budget. This grouping is illustrated in Figure VI.3.

We thus find that while high prime contract award states such as California, Texas, and Florida benefit greatly from NASA procurement spending, so also do states such as Illinois, which will receive only a relatively small portion of the FY 1990 NASA direct procurement budget. In 1990, NASA procurement spending will create (directly and indirectly) $550 million in industry sales and 5,700 jobs in Illinois. Further, as noted, in this state for every direct dollar of NASA spending, an additional 10 dollars of spending are generated indirectly by the NASA procurement budget.

This at first glance may seem counterintuative, since Illinois is not generally considered to be a state that benefits greatly from the Space Program. However, Illinois does benefit substantially from NASA spending. Its industries produce the goods and services required indirectly by the recipients of NASA procurement awards: capital goods, electronic components, scientific instruments, chemical products, primary and fabricated metals products, specialized business services, etc. Further, because of the widely based, indirect nature of these economic benefits to the state, Illinois will benefit greatly from NASA procurement spending in other states on a wide variety of programs, and its benefits are not tied to a specific contract, project, or program.

Table VI.8

Categorization of the States Benefiting Most From Proposed FY 1990 NASA Procurement Expenditures

Category A

Major Prime Contract Award States

California	Alabama
Texas	Louisiana
Florida	Utah
Maryland	Virginia

Category B

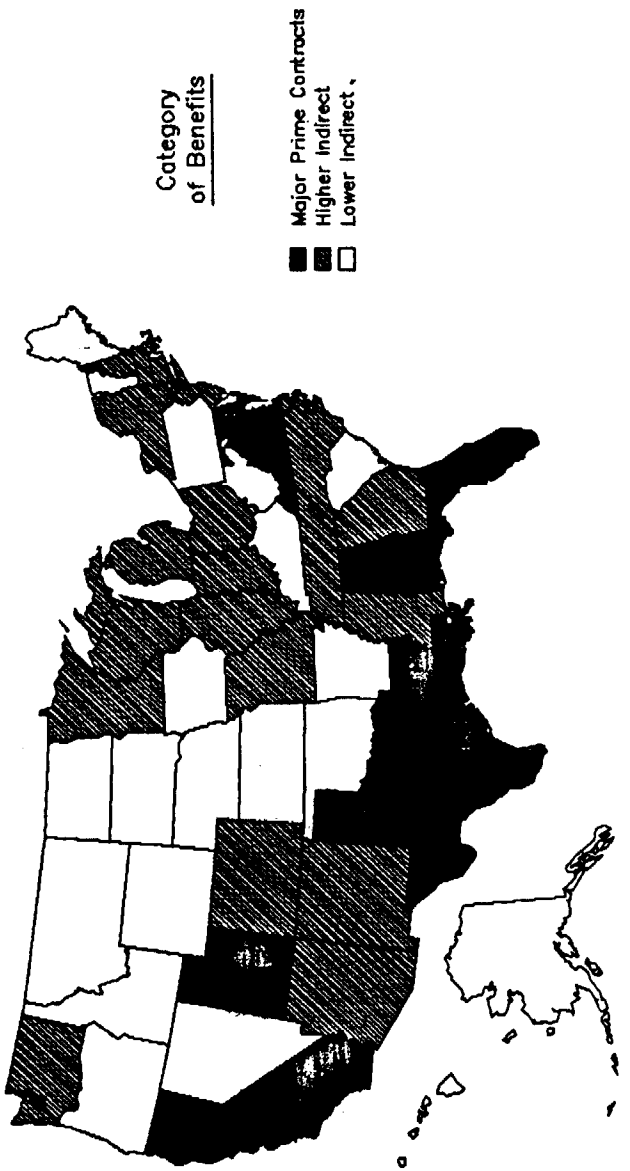
States Benefiting Indirectly From the U.S. Space Program

Colorado	Washington
New Jersey	Massachusetts
New York	Missouri
Arizona	Wisconsin
Mississippi	New Hampshire
Ohio	New Mexico
Indiana	Georgia
Illinois	Connecticut
Michigan	North Carolina
Tennessee	Minnesota

Source: Management Information Services, Inc., 1989

Figure VI.3

States Benefiting Most from U.S. Space Program
Fiscal Year 1990



Source: Management Information Services, Inc.; 1989.

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Detailed Occupational Jobs Created by Proposed FY 1990 NASA Procurement Expenditures

Occupational Title	Jobs
Legislators	2
Public administration, chief executives	7
Public administration, officials	159
Administrators, protective services	16
Financial managers	683
Personnel & labor relations	494
Purchasing managers	1,251
Managers, marketing, advertising	1,175
Administrators, education	473
Managers, medicine & health	14
Managers, properties & real estate	388
Postmasters	57
Funeral directors	64
Managers & administrators, n.e.c.	14,107
Accountants & auditors	2,604
Underwriters	24
Other financial officers	1,069
Management analysts	355
Personnel & training specialists	686
Purchasing agents, farm products	18
Buyers, wholesale & retail trade	250
Purchasing agents & buyers, n.e.c.	1,472
Business & promotion agents	56
Construction inspectors	69
Inspectors, except construction	139
Management related, n.e.c.	802
Architects	181
Aerospace engineers	3,441
Metallurgical engineers	344
Mining engineers	52
Petroleum engineers	155
Chemical engineers	476
Nuclear engineers	50
Civil engineers	897
Agricultural engineers	3
Electrical engineers	5,304
Industrial engineers	2,288
Mechanical engineers	2,413
Marine engineers	98
Engineers, n.e.c.	986
Surveyors & mapping	46
Computer systems analysts	1,620
Operations & systems researchers	1,359
Actuaries	18
Statisticians	40
Mathematical scientists, n.e.c.	123
Physicists & astronomers	27
Chemists, except biochemists	412
Atmospheric and space scientists	53
Geologists & geodesists	256

Physical scientists, n.e.c.	20
Agricultural scientists	12
Biological & life scientists	27
Forestry & conservation scientists	47
Medical scientists	5
Physicians	91
Dentists	19
Veterinarians	44
Optometrists	19
Podiatrists	1
Health diagnosing, n.e.c.	4
Registered nurses	367
Pharmacists	139
Dietitian	25
Inhalation therapists	11
Occupational therapists	15
Physical therapists	7
Speech therapists	68
Therapists, n.e.c.	14
Physicians' assistants	28
Earth, environmental science teachers	1
Biological science teachers	5
Chemistry teachers	4
Physics teachers	2
Psychology teachers	3
Economics teachers	3
History teachers	3
Political science teachers	2
Sociology teachers	0
Social science teachers, n.e.c.	1
Engineering teachers	5
Mathematical science teachers	7
Computer science teachers	10
Medical science teachers	5
Health specialties teachers	7
Business teachers	6
Agriculture teachers	0
Art & music teachers	5
Physical education teachers	2
Education teachers	3
English teachers	5
Foreign language teachers	3
Law teachers	1
Social work teachers	1
Theology teachers	1
Trade & industrial teachers	2
Home economics teachers	0
Postsecondary, subject not specified	19
Teachers, prekindergarten & kindergarten	336
Teachers, elementary school	2,784
Teachers, secondary school	2,429
Teachers, special education	11
Teachers, n.e.c.	560
Counselors, educational	170
Librarians	171
Archivists & curators	16
Economists	316
Psychologists	103

Sociologists	1
Social scientists, n.e.c.	12
Urban planners	7
Social workers	105
Recreation workers	8
Clergy	55
Religious workers, n.e.c.	15
Lawyers	1,099
Judges	11
Authors	134
Technical writers	329
Designers	1,029
Musicians & composers	171
Actors & directors	83
Painters & artists	324
Photographers	203
Dancers	10
Artists, n.e.c.	61
Editors & reporters	402
Public relations specialists	319
Announcers	57
Athletes	31
Clinical laboratory technicians	40
Dental hygienists	13
Health record technicians	7
Radiologic technicians	16
Licensed practical nurses	107
Health technicians, n.e.c.	140
Electrical technicians	2,404
Industrial engineering technicians	11
Mechanical engineering technicians	577
Engineering technicians, n.e.c.	1,653
Drafting occupations	1,174
Surveying & mapping technicians	184
Biological technicians	43
Chemical technicians	269
Science technicians, n.e.c.	344
Airplane pilots & navigators	227
Air traffic controllers	8
Broadcast equipment operators	43
Computer programmers	2,736
Tool programmers	8
Legal assistants	157
Technicians, n.e.c.	1,132
Supervisors & proprietors, sales	3,716
Insurance sales occupations	417
Real estate sales occupations	596
Securities sales occupations	160
Advertising sales occupations	224
Sales occupations, other	999
Sales engineers	167
Sales representatives	3,000
Sales workers, motor vehicles	245
Sales workers, apparel	536
Sales workers, shoes	130
Sales workers, furniture	162
Sales workers, radio, TV	160
Sales workers, hardware	192

Sales workers, parts	185
Sales workers, other commodities	1,701
Sales counter clerks	192
Cashiers	2,442
Street sales workers	477
News vendors	502
Demonstrators, sales	62
Auctioneers	11
Sales support occupations, n.e.c.	44
Supervisors, general office	475
Supervisors, computer equipment	222
Supervisors, financial records	173
Chief communications operators	18
Supervisors; distribution & scheduling	676
Computer operators	2,555
Peripheral equipment operators	26
Secretaries	7,733
Stenographers	308
Typists	1,764
Inverviewers	182
Hotel clerks	120
Transportation agents	382
Receptionists	650
Information clerks, n.e.c.	360
Classified-ad clerks	10
Correspondence clerks	37
Order clerks	322
Personnel clerks	146
Library clerks	99
File cleks	432
Records clerks	147
Bookkeepers, accounting clerks	3,424
Payroll clerks	683
Billing clerks	315
Cost & rate clerks	139
Billing & calculating machine operators	100
Duplicating machine operators	151
Mail preparing machine operators	21
Office machine operators, n.e.c.	226
Telephone operators	321
Telegraphers	15
Communications equip. operators, n.e.c.	33
Postal clerks	663
Mail carriers	686
Mail clerks, exc. postal service	265
Messengers	302
Dispatchers	327
Production ooordinatos	1,307
Shipping & receiving clerks	1,284
Stock & inventory clerks	2,156
Meter readers	95
Weighers & checkers	299
Expediters	562
Material recording clerks, n.e.c.	207
Insurance investigators	153
Investigators, exc. insurance	517
Eligibility clerks, welfare	13
Bill & account clerks	172

General office clerks	1,333
Bank tellers	323
Proofreaders	36
Data-entry keyers	883
Statistical clerks	416
Teachers aides	598
Administrative support, n.e.c.	542
Supervisors, firefighting	13
Supervisors, police	22
Supervisors, guards	146
Fire inspection	20
Firefighting occupations	71
Police & detectives	129
Sheriffs & bailiffs	30
Correctional institution officers	43
Crossing guards	14
Guards & police, exc. public service	1,280
Protective service occupations, n.e.c.	29
Supervisors, food preparation	237
Bartenders	417
Waiters & waitresses	1,811
Cooks, except short order	1,658
Short-order cooks	103
Food counter occupations	442
Kitchen workers	184
Waiters'/waitresses' assistants	500
Miscellaneous food preparation	768
Dental assistants	19
Health aides, except nursing	78
Nursing aides	283
Supervisors, cleaning workers	155
Maids & housemen	417
Janitors & cleaners	3,458
Elevator operators	13
Pest control occupations	38
Supervisors, personal services	18
Barbers	160
Hairdressers & cosmetologists	983
Attendants, amusement facilities	141
Guides	31
Ushers	10
Transportation attendants	224
Baggage porters	42
Welfare service aides	16
Child care workers	554
Personal service occupations, n.e.c.	155
Farmers, except horticultural	1,316
Horticultural specialty farmers	9
Managers, farms, except horticultural	64
Managers, horticultural specialty farms	12
Supervisors, farm workers	55
Farm workers	1,143
Marine life cultivation workers	0
Nursery workers	33
Supervisors, related agricultural	137
Groundskeepers & gardeners	374
Animal caretakers	103
Graders & sorters	32

Supervisors, forestry & logging workers	11
Forestry workers, except logging	23
Timber cutting & logging occupations	275
Captains & officers, fishing vessels	3
Fishers	63
Hunters & trappers	5
Supervisors, mechanics & repairers	609
Automobile mechanics	945
Automobile mechanic apprentices	5
Bus & truck engine mechancis	694
Aircraft engine mechanics	881
Small engine repairers	156
Automoile body repairers	204
Aircraft mechanics, except egine	887
Heavy equipment mechanics	790
Farm equipment mechanics	77
Industrial machinery repairers	2,033
Machinery maintenance occupations	76
Electronic repairers, commun. equipment	915
Data processing equipment repairers	361
Household appliance repairers	59
Telephone line installers	130
Telephone installers	840
Miscellaneous electronic equip. repairers	238
Heating & air conditioning mechanics	416
Camera & watch repairers	69
Locksmiths	46
Office machine repairers	183
Mechanical control repairers	91
Elevator installers	44
Millwrights	224
Specified mechanics & repairers, n.e.c.	1,189
Not specified mechanics & repairers	601
Supervisors; brickmasons	13
Supervisors, carpenters	29
Supervisors, electricians	107
Supervisors, painters	22
Supervisors, plumbers	35
Supervisors, n.e.c.	785
Brickmasons & stonemasons	272
Brickmason & stonemason apprentices	7
Tile setters	49
Carpet installers	177
Carpenters	2,490
Carpenter apprentices	19
Drywall installers	179
Electricians	1,713
Electrician apprentices	90
Electrical power installers	275
Painters	657
Paperhangers	56
Plasterers	71
Plumbers	1,340
Plumber apprentices	6
Concrete & terrazzo finishers	71
Glaziers	85
Insulation workers	150
Paving & surfacing equipment operators	2

Roofers	225
Sheetmetal duct installers	156
Structural metal workers	163
Drillers, earth	17
Construction trades, n.e.c.	291
Supervisors, extractive occupations	311
Drillers, oil well	378
Explosives workers	139
Mining machine operators	110
Mining occupations, n.e.c.	190
Supervisors, production occupations	7,221
Tool & die makers	1,272
Tool & die maker apprentices	221
Precision assemblers, metal	343
Machinists	3,476
Machinist apprentices	178
Boilermakers	136
Precision grinders	154
Patternmakers, metal	19
Lay-out workers	227
Precious stones & metals workers	43
Engravers, metal	43
Sheet metal workers	1,523
Sheet metal worker apprentices	13
Miscellaneous precision metal workers	0
Patternmakers & model makers, wood	30
Cabinet makers & bench carpenters	56
Furniture & wood finishers	40
Dressmakers	146
Tailors	55
Upholsterers	126
Shoe repairers	47
Miscellaneous precision apparel workers	11
Hand molders & shapers, except jewelers	14
Patternmakers	182
Optical goods workes	135
Dental laboratory technicians	30
Bookbinders	36
Electrical equipment assemblers	2,047
Miscellneous precision workers n.e.c.	292
Butchers & meat cutters	258
Bakers	92
Food batchmakers	22
Inspectors & testers	1,556
Adjusters & calibrators	100
Water & sewage treatment plant operators	145
Power plant operators	92
Stationary engineers	387
Miscellaneous plant & system operators	162
Lathe & turning machine set-up operators	175
Lathe & turning machine operators	499
Milling & planing machine operators	88
Stamping press machine operators	683
Rolling machine operators	115
Drilling machine operators	467
Grinding & polishing maciine operators	1,266
Forging machine operators	68
Numerical control machine operators	130

Miscellaneous machine operators	534
Fabricating machine operators, n.e.c.	108
Molding & casting machine operators	503
Metal plating machine operators	394
Heat treating equipment operators	135
Miscellaneous metal machine operators	45
Wood lathe machine operators	28
Sawing machine operators	188
Shaping & joining machine operators	7
Nail & tacking machine operators	22
Misc. woodworking machine operators	29
Printing machine operators	649
Photoengravers & lithographers	88
Typesetters & compositors	210
Miscellaneous printing machine operators	55
Winding & twisting machine operators	233
Knitting & weaving machine operators	85
Textile cutting machine operators	10
Textile sewing machine operators	1,024
Shoe machine operators	51
Pressing machine operators	296
Laundering & dry cleaning mach. operators	171
Miscellaneous textile machine operators	125
Cementing & gluing machine oprators	298
Packaging & filling machine operators	908
Extruding & forming machine operators	219
Mixing & blending machine operators	341
Separating machine operators	139
Compressing machine operators	74
Painting machine operators	657
Roasting & baking machine operators	1
Washing & cleaning machine operators	27
Folding machine operators	63
Furnace & oven operators	854
Crushing & grinding machine operators	63
Slicing & cutting machine operators	557
Motion picture projectionists	13
Photographic process machine operators	156
Miscellaneous machine operators, n.e.c.	4,078
Machine operators, not specified	1,025
Welders & cutters	2,375
Solderers & brazers	395
Assemblers	6,523
Hand cutting & trimming occupations	37
Hand molding & forming occupations	67
Hand painting & decorating occupations	315
Hand engraving & printing occupations	12
Hand grinding & polishing occupations	39
Miscellaneous hand working occupations	90
Production inspectors & examiners	3,579
Production testers	495
Production samplers & weighers	18
Graders & sorters, except agricutlural	111
Supervisors, motor vehicle operators	56
Truck drivers, heavy	5,124
Truck drivers, light	768
Driver-sales worker	167
Bus drivers	1,100

Taxicab drivers & chauffeurs	482
Parking lot attendants	57
Motor transportation occupations, n.e.c.	4
Railroad conductors & yardmasters	67
Locomotive operating occupations	202
Railroad brake & switch operators	139
Rail vehicle operators, n.e.c.	33
Ship captains & mates	156
Sailors & deckhands	44
Bridge & lighthouse tenders	3
Supervisors, material moving equipment	69
Operating engineers	320
Longshore equipment operators	0
Hoist & winch operators	113
Crane & tower operators	490
Excavating & loading machine operators	142
Grader, dozer, & scraper operators	177
Indust. truck & tractor equip. operators	957
Misc. material moving equipment operators	414
Supervisors, equipment cleaners, n.e.c.	21
Helpers, mechanics & repairers	63
Helpers, construction trades	256
Helpers, surveyor	18
Helpers, extractive occupations	19
Construction laborers	956
Production helpers	338
Garbage collectors	170
Stevedores	102
Stock handlers & baggers	884
Machine feeders & offbearers	271
Freight, stock & material handlers, nec	1,197
Garage & service station related occupat.	360
Vehicle washers & equipment cleaners	434
Hand packers & packagers	575
Laborers, except construction	2,664
Total	236,679

Source: Management Information Services, Inc.; 1989.